

# Aircraft Carrier Flight and Hangar Deck Fire Protection: History and Current Status

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**NAVAL AIR WARFARE CENTER WEAPONS DIVISION  
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## **FOREWORD**

This report documents a briefing on aircraft carrier fire protection. The stated goal of the briefing was to provide an historical frame of reference for assessing flight and hangar deck fire-protection features and firefighting capability as part of the Live Fire Test and Evaluation (LFT&E) analysis process for the proposed CVNX future carrier. The work is being funded by the Department of Defense Office of LFT&E through the CVNX Program Office (PMS-378).

This report was reviewed for technical accuracy by Vince Homer.

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## INTRODUCTION

This presentation covers the history and current status of fire protection on aircraft carrier flight decks and hangar decks (Figure 1). Fire protection on aircraft carriers is a joint responsibility of the Naval Sea Systems Command (NAVSEA) and the Naval Air Systems Command (NAVAIR). Shown in Figure 2 are the points of contact and individuals from other organizations who contribute to aircraft-carrier fire protection. Figure 3 provides an outline of what is covered in this report, beginning with the significant physical characteristics of aircraft carriers that are relevant to fire protection. We discuss specifically the fire-hazardous nature of carrier operations and focus on some of the concerns relative to air-launched ordnance. We review firefighting systems, including the firefighting agents currently in use, as well as the current tactics for fighting fires on the flight deck and the hangar deck. The review of the history of carrier fires includes some of the lessons learned, and the research and development programs that resulted from those fires. Some recent program initiatives under NAVAIR project W1819 and a list of some current shortcomings and future concerns are also included.

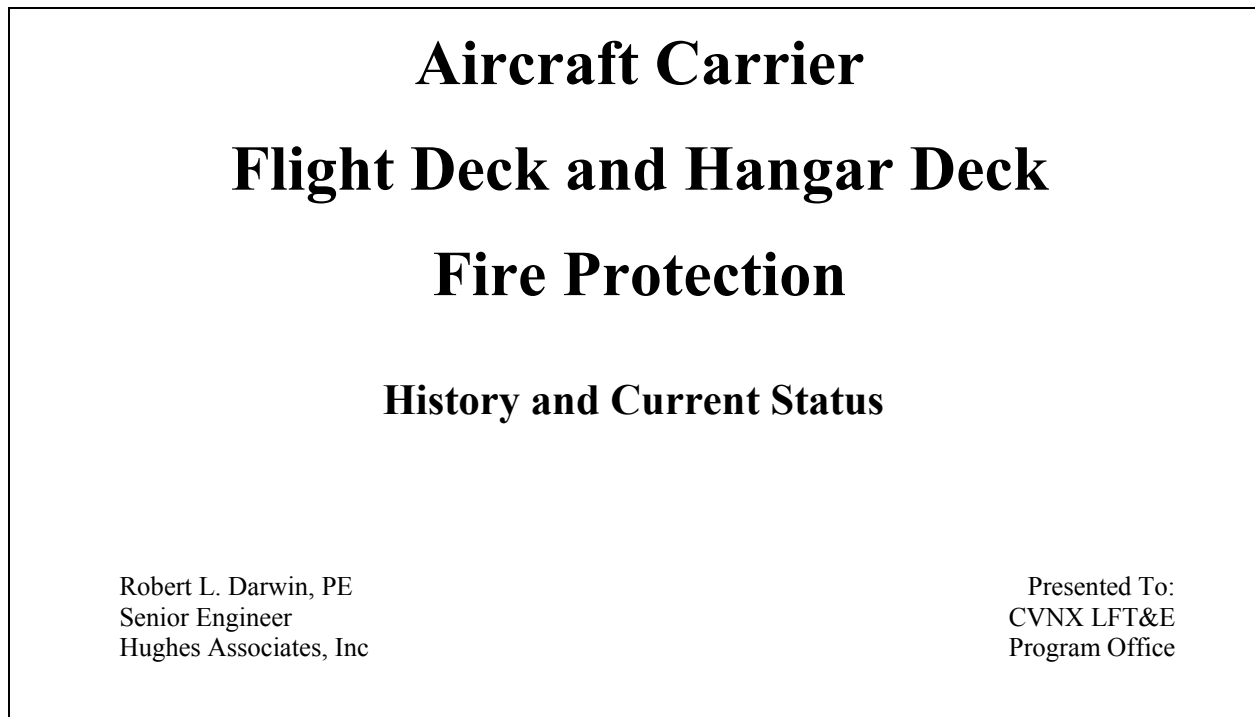


FIGURE 1. Introductory Page.

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FIGURE 2. Points of Contact.

## **Outline of Briefing**

Aircraft Carrier Orientation  
    Significant Dimensions and Characteristics  
    Pertinent Operations  
    Flight Deck & Hangar Deck  
Fire Hazardous Nature of Carrier Operations  
Ordnance Concerns  
Review of Firefighting Agents  
Flight Deck Conflagration Control Systems  
Hangar Deck Firefighting Systems  
Current Firefighting Tactics  
    Flight Deck  
    Hangar Deck  
Review of Carrier Fire History  
Lessons Learned and R&D  
Recent Program Initiatives Under NAVAIR W1819  
Current Shortcomings & Future Concerns

FIGURE 3. Outline of Presentation.



## BACKGROUND

In response to a request from the Department of Defense (DOD) Office of Live Fire Test and Evaluation (LFT&E), the CVNX Program Office (PMS-378) asked NAVSEA Damage Control and Fire Protection Division (SEA 05L4) to prepare a briefing on aircraft carrier fire protection. The briefing was to provide an historical frame of reference for assessing flight and hangar deck fire-protection features and firefighting capability as part of the LFT&E analysis process for the proposed CVNX (carrier vessel nuclear experimental) future carrier.

SEA 05L4 requested that NAVAIR provide the services of Mr. Robert L. Darwin of Hughes Associates, Inc. (HAI) to assemble and present the briefing. HAI, a fire-protection engineering consulting firm, is currently a support contractor to the Fire Research Office, Engineering Sciences Division, of the Naval Air Warfare Center Weapons Division (NAWCWD) China Lake. Mr. Darwin was formerly the Director of the NAVSEA Fire Protection Division and has been involved in carrier fire protection for over 30 years

The briefing was presented on 22 February 2001 to representatives of the LFT&E office and again on 29 June 2001 for the new PMS-378 LFT&E Coordinator, CDR Chris Meyer. At that time, it was decided that the presentation should be recorded as permanent documentation. NAWCWD China Lake agreed to publish the presentation to establish a formal Navy archival record. This report contains the briefing slides and accompanying narrative. The presenter was specifically requested to include in the presentation his own assessment of possible “shortcomings in carrier fire protection and future concerns.” These were provided as the last five slides in the briefing. The material presented represents the opinion of the presenter and does not necessarily reflect the position of the U.S. Navy.

## CURRENT AND FUTURE CARRIERS

Figure 4 provides a list of the current commissioned carriers. Currently, 12 carriers are in the Navy, eight of which are considered *Nimitz*-class carriers, which means they are CVN-68 or higher. There are three older pre-*Nimitz* carriers, one of which is also nuclear powered (USS *Enterprise*). To put this on a time perspective, since the *Nimitz* was commissioned in 1975, the *Nimitz*-class carriers have been around for over 25 years.

**Current USN Aircraft Carriers**

CV-63	KITTY HAWK
CVN-65	ENTERPRISE
CV-67	JOHN F. KENNEDY
CVN-68	CHESTER W. NIMITZ
CVN-69	DWIGHT D. EISENHOWER
CVN-70	CARL VINSON
CVN-71	THEODORE ROOSEVELT
CVN-72	ABRAHAM LINCOLN
CVN-73	GEORGE WASHINGTON
CVN-74	JOHN C. STENNIS
CVN-75	HARRY S. TRUMAN
CVN-76	RONALD REAGAN

FIGURE 4. Current Aircraft Carriers.

Figure 5 shows future Navy aircraft carriers. The CVN-77, the *George H. W. Bush*, is now under construction at Newport News New Shipbuilding. The CVN-77 could be a transition ship between the *Nimitz*-class and the CVNX. The CVN-77, which may begin construction within the next year, is scheduled to replace the *Kitty Hawk* in about 2008. The three most significant differences between the CVN-77 and prior *Nimitz*-class carriers is that the CVN-77 will have (1) a redesigned island structure, (2) an integrated combat system, and (3) considerably more in the way of automation and remote control from the bridge.

CVNX-1 will begin construction in about 2006 and will ultimately replace the *Enterprise* in about 2013. As currently envisioned, CVNX-1 will have a redesigned propulsion plant as well as a new electrical-generation and distribution system. The steam catapults will be replaced with the new electromagnetic aircraft launching system commonly referred to as EMALS (electronic aircraft launch systems). CVNX-2, construction date currently unknown, will perhaps have a redesigned flight deck. It will probably have many more sensors, in an attempt to reduce watchstanding, and may have an electromagnetic aircraft-recovery system to replace the steam arresting gear. The overall goal of CVNX-2 and future CVNX ships is to try to reduce crew workload to enhance safety and reduce operation and maintenance (O&M) costs by major redesign and providing more automation and remote control.

### Future USN Aircraft Carriers

CVN-76 RONALD REAGAN (under construction)

#### CVN-77

- will replace CV-63 in 2008
- begin construction in 2001
- redesigned island to reduce radar signature
- integrated combat systems
- automated controls on carrier bridge

#### CVNX-1

- will replace CVN-65 in 2013
- begin construction in 2006
- redesigned propulsion plan
- new electrical generation and distribution
- EMALS to replace steam catapults

#### CVNX-2

- smart sensors (reduce watch standing)
- flight deck redesign
- electromagnetic aircraft recovery system (EARS)
- goal is to reduce crew workload, enhance safety and reduce O & M costs

FIGURE 5. Future Aircraft Carriers.

## CARRIER ORIENTATION

Figure 6 is a photograph of the newest aircraft carrier, the CVN-75, which is the USS *Harry S Truman*. The ship's overall length is almost 1100 feet, and the maximum width of the flight deck is 255 feet. That is actually significant from a firefighting standpoint because hoses for firefighting are stored in the catwalks on both the port and starboard side, and hoses have to be stretched across that maximum width. We learned years ago that we needed to provide additional hose on the reels or the racks that serve the maximum width of the flight deck. The beam of the ship at the water line is almost 135 feet, and the flight deck occupies about 4½ acres. Admittedly, that sounds like a lot of real estate, but when you are loaded with aircraft and involved in trying to conduct launching and recovery operations, then the flight deck can get very crowded in spite of the 4½ acres.

The full load displacement for a *Nimitz*-class carrier is almost 100,000 tons and there are approximately 6,000 people on the ship, split fairly evenly between ship's company and the deployed airwing. The height of the flight deck above the waterline is about 60 feet, which means to abandon ship from the flight deck requires a considerable fall into the water. In fact, during the flight deck fire on the *Forrestal* in 1967, several people did go overboard and in most cases they survived. We discuss that incident subsequently. A couple of other statistics: the height from the keel to the top of the mast is about equivalent to a 20-story building, roughly 200 feet. The ship has two nuclear reactors and two anchors, each anchor weighing about 30 tons.

Several things come in groups of four. There are four shafts driven by the propulsion plant, four propellers, four aircraft elevators and four catapults—two on the front of the bow and two on the angle deck. Also four cross-deck pendants constitute the arresting gear.



FIGURE 6. *Nimitz*-Class Carrier.

Figure 7 is a picture looking directly on the bow. The width of the bow is about 80 feet. The angle deck to the right is about 800 feet long. The two bow catapults are visible and to the right would be the two waist catapults, although they are hard to see in this photograph. The white cylinders on each side of the bow are two of the CIWS Phalanx 20-mm self-protection guns. The ship will have three or four of those, depending on the year of construction. Each of the two NATO Sea Sparrow Launchers has eight missile-launch tubes. For electric power generation, eight ship service turbo generators have about 8 MW each.

Figure 8 shows the island structure. Each one of those pieces of yellow gear, as they are called, represents support equipment provided by NAVAIR to support air operations. Other equipment includes a crash crane known as “tilley,” a forklift, tow tractors, and jet engine starting units. The white vehicles are the special flight-deck fire trucks.



FIGURE 7. View of Bow.



FIGURE 8. View of Island.

Figure 9 is another view of the angle deck. The advent of the angle deck years ago made a great contribution to fight deck safety because aircraft could be stored on the bow. An aircraft could attempt to land on the angle, and if he was unable to engage the arresting gear he could safely fly around for another attempt without the fear of crashing into the aircraft on the bow. We

subsequently discuss an incident on the flight deck of the *Nimitz* in 1981 where an aircraft lined up on the foul line rather than the centerline and plowed into a pack of F-14s on the bow.



FIGURE 9. Angle Deck.

Figure 10 shows how closely packed aircraft can be when they are parked. All Navy aircraft have the ability to fold their wing tips to get a tighter stacking pattern on the flight deck. Typically a carrier can have approximately 80 aircraft, both fixed wing and helicopters. F-14 Tomcats, F/A-18 Hornets, EA6B Prowlers provide electronic countermeasures, while anti-submarine warfare would probably be handled by S-3 Vikings. The E-2C Hawkeyes provide early warning, and the transport of people and logistics are handled by the C-2 Greyhounds. Helicopters are primarily the SH-60s.





FIGURE 10. Parking on Bow.

Figure 11 shows aircraft parked on the bow in heavy seas. In this particular case waves are projecting up over the flight deck, which is normally 60 above the water.



FIGURE 11. Bow in Heavy Seas.

Figure 12 illustrates the tight packing of aircraft and the resulting congestion. Of course that does make it difficult for firefighting; hose teams have difficulty getting into the center of the pack. It is especially difficult for the little fire truck to get in there, though they try to leave a firelane to facilitate access.



FIGURE 12. Aircraft Tightly Packed.

Figure 13 shows a catapult shot off the No. 2 catapult on the bow at the same time aircraft are parked on the starboard side. Parking patterns are designated as are aircraft movement paths, depending on where you are in your cyclic operations, in launch or recovery. Figure 14 shows how aircraft would typically be parked and maneuvered for the first or second launch of the day. Aircraft are parked on the starboard side to feed catapult 1 and 2. The little arrows show how the aircraft is moved up to either No. 1 or No. 2 catapults and aircraft parked aft are moved forward to be shot off the waist catapults.

The bottom part of this figure shows the parking pattern on the hangar bay. There are four aircraft elevators. No. 1 aircraft elevator comes down on the starboard side of hangar bay 1, elevator No. 2 comes down on the starboard side of hangar bay 2, and elevators 3 and 4 come down on both the port and starboard side of hangar bay No. 3. You can see the three hangar bays with the division doors that separate the hangar bays. The division doors came about really as a result of the Kamikaze attacks in World War II as an attempt to limit the maximum fire area. These are very thick steel doors and the object is to try to confine an incident to the bay of origin.





FIGURE 13. Launch No. 2 Catapult.

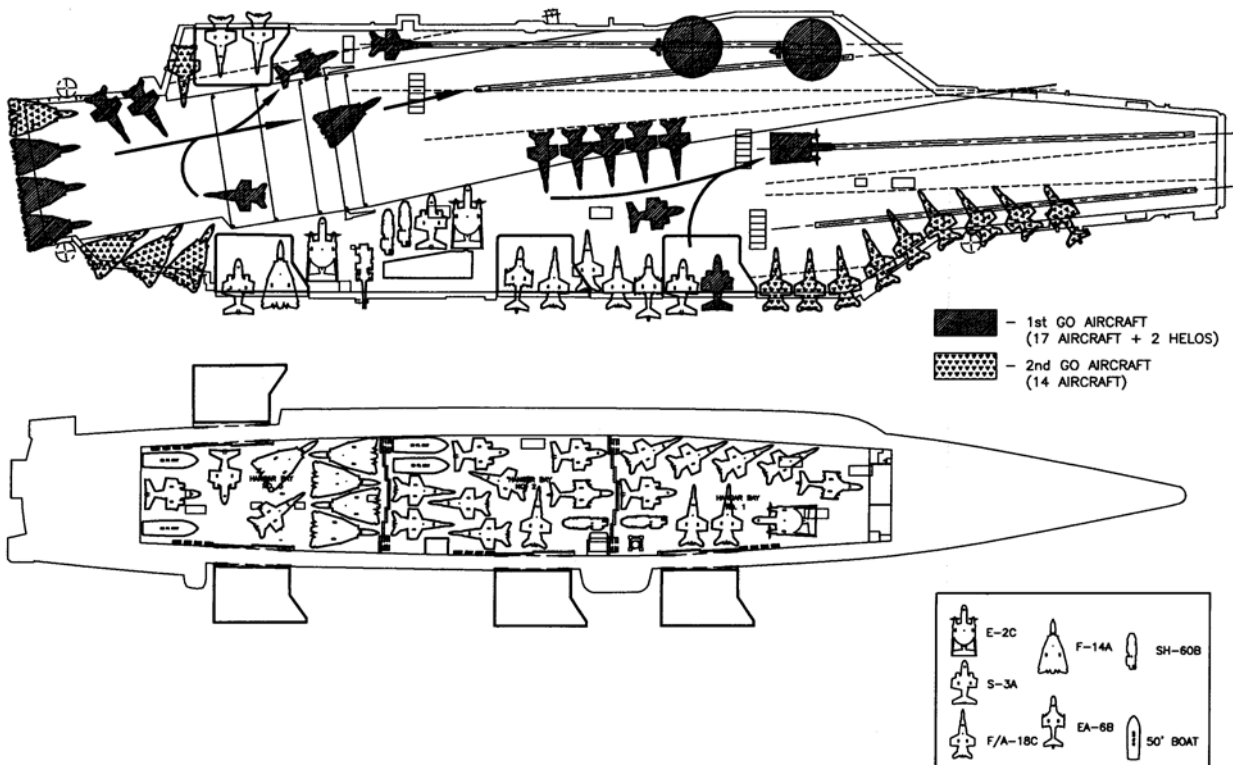


FIGURE 14. Pre-Launch Spotting Pattern.

Figure 15 shows a typical parking pattern for recovery of aircraft. The difference here is that all the aircraft have to be parked outboard of the foul line that defines the angle deck so that the angle deck is left clear for recovery. Out of necessity, aircraft are parked very close to that foul line. One of our flight deck accidents in 1981 occurred when this parking pattern was in place. In fact, the incident occurred later on in the recovery when they began to stow aircraft up on the port side of the bow. Figure 16 illustrates the spotting arrangement in effect at the time of the *Nimitz* crash.

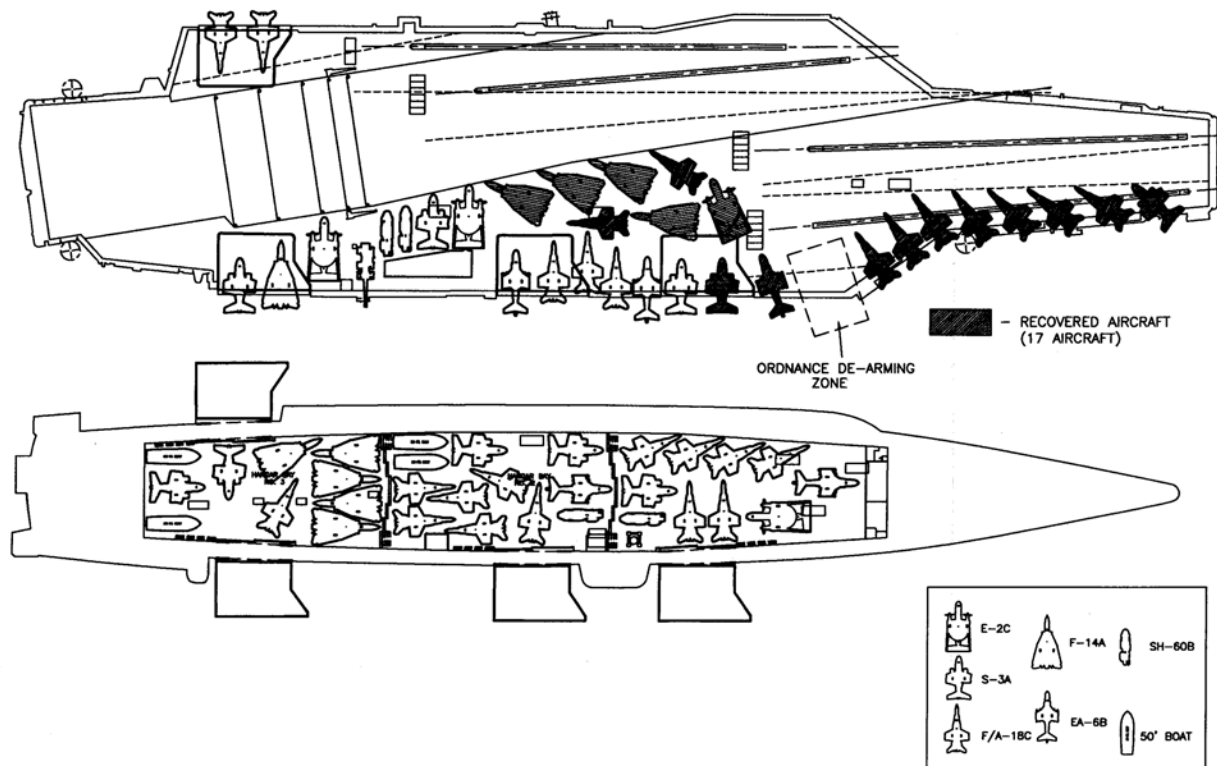


FIGURE 15. Second Recovery Spotting Pattern.

Figure 17 shows a typical arrested landing where the tail hook of the aircraft catches one of the four cross deck pendants. In a situation where a pilot is injured, there is damage to the aircraft, or the aircraft is low on fuel so it may not have enough fuel to go around again should he fail to catch the crossdeck pendants, a barricade consisting of nylon webbing is stretched across a couple of steel pylons (Figure 18). This is erected for a "must-catch" situation. Some manual evolution is involved in this but during drills they usually try to get it up in a couple minutes. Figure 19 illustrates how it works. The airplane comes in and is trapped by the nylon webbing. Usually a little damage occurs to the airplane, but most of the aircraft is salvaged and the pilot is saved. Figure 20 is a photograph of an actual arrested landing using the barricade.

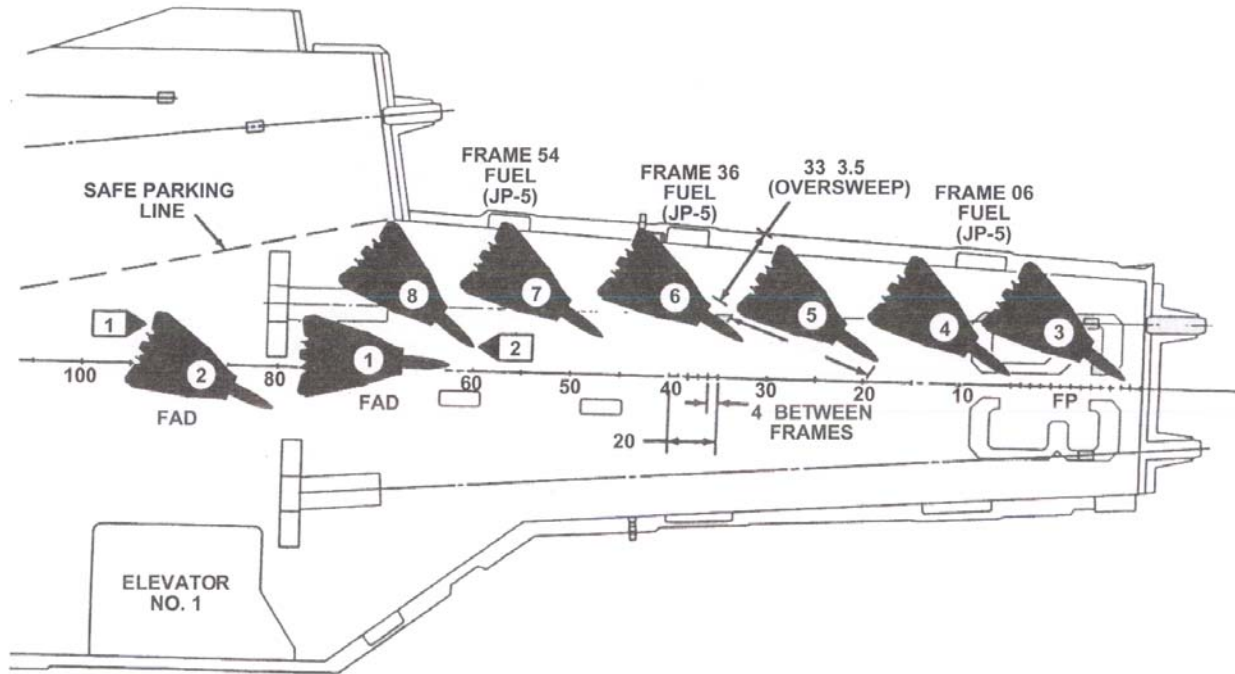


FIGURE 16. Bow Recovery Spotting Pattern.



FIGURE 17. Arrested Landing.

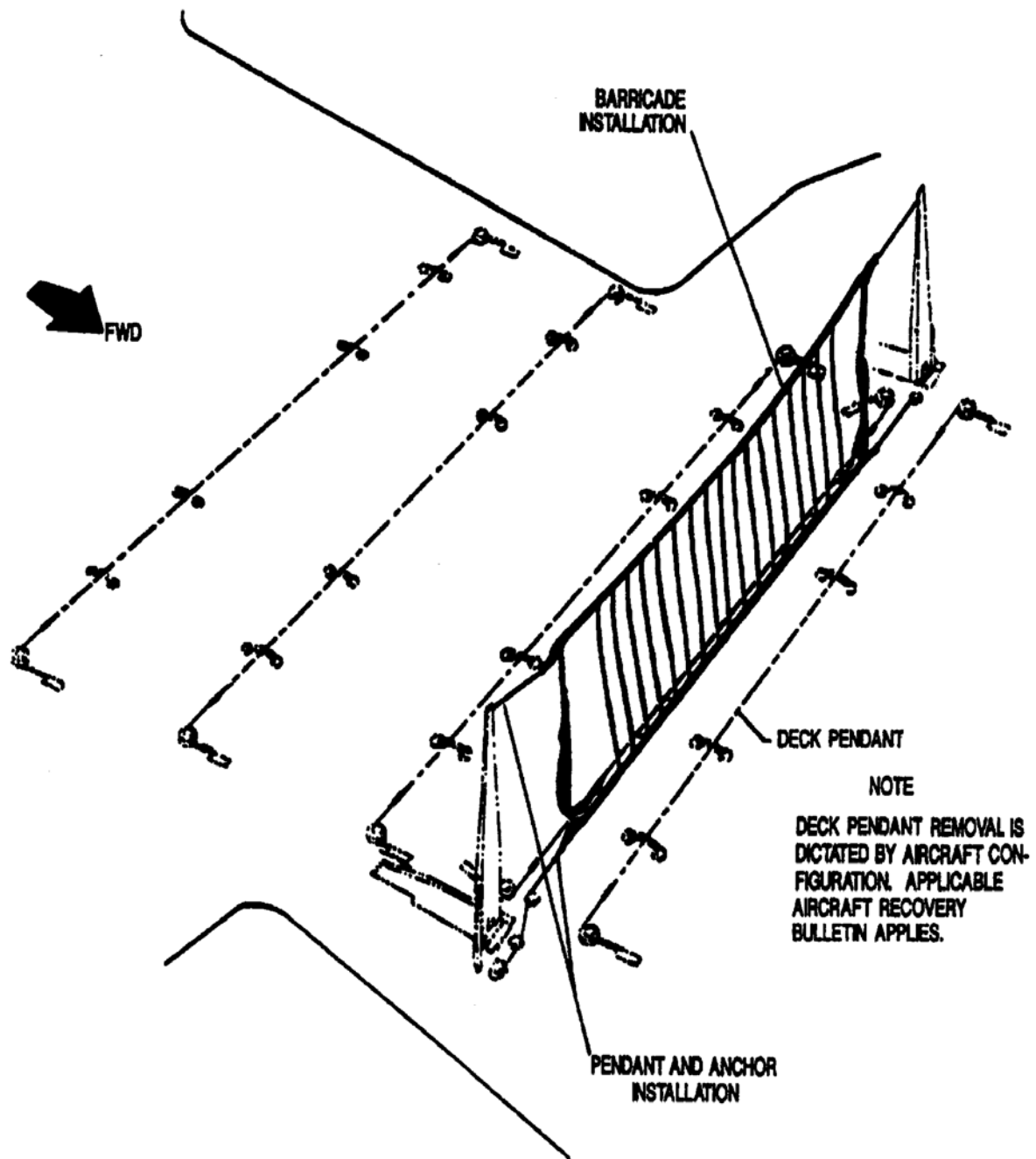


FIGURE 18. Landing Barricade.

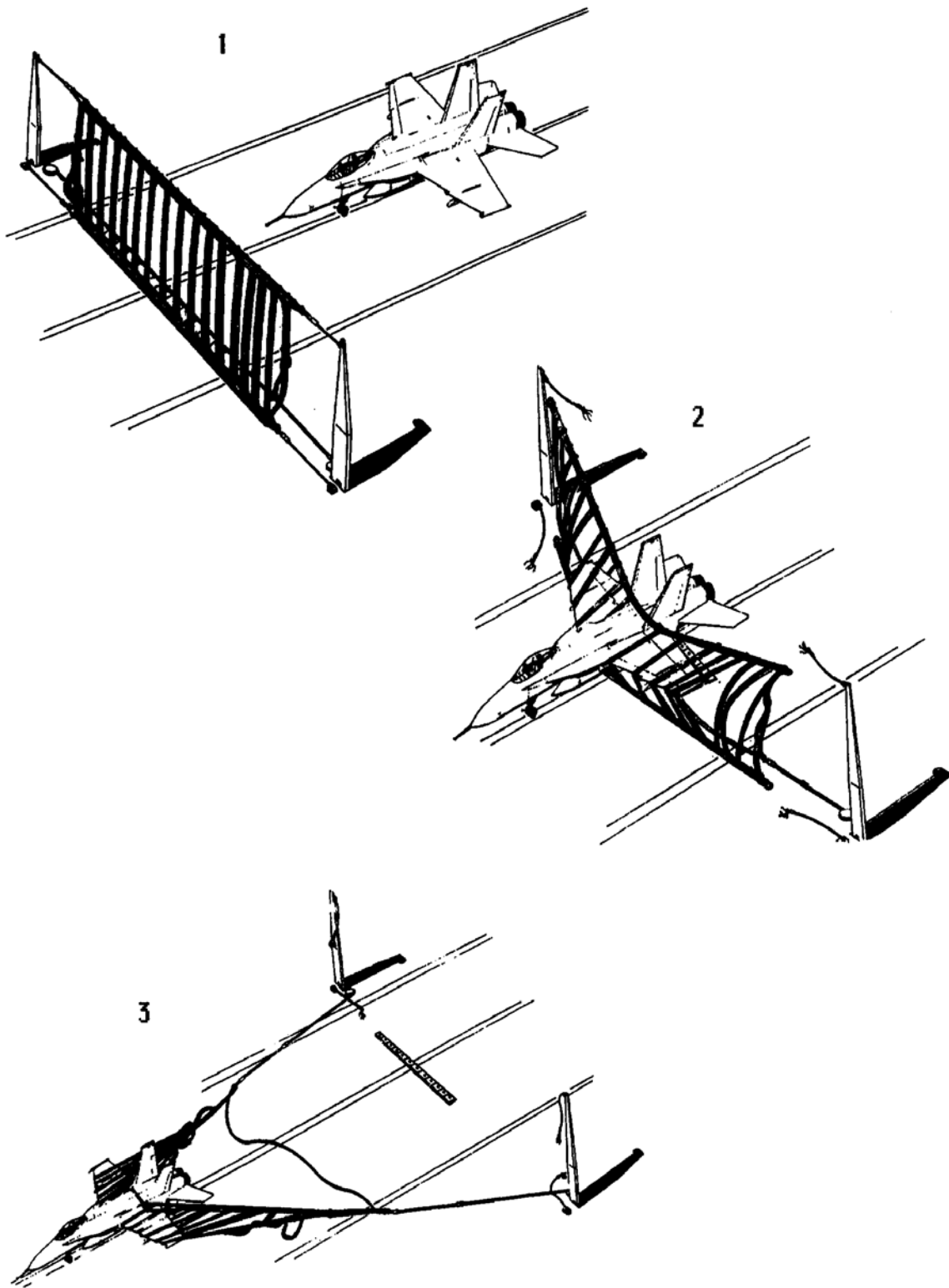


FIGURE 19. Barricade Operation.





FIGURE 20. Actual Barricade Landing.

The hangar bay can be very congested (Figure 21). During checkout or maintenance evolutions, airplanes often have their cockpits open when they are on the hangar bay. That is significant relative to the overhead sprinkling system. The hangar bay is protected by an overhead aqueous film-forming foam (AFFF) sprinkler system that discharges a solution consisting of 94% seawater. Seawater in a cockpit certainly does a lot of damage, so we have to be careful to design a fire-protection system for the hangar bay that is not prone to accidental or inadvertent trip. Should that system go off when there is no fire much damage could occur.

Figure 22 is another photograph in the hangar bay and you can see the open cockpits. The ceiling height in the hangar varies, but most of it has about a 25-foot overhead (Figure 23). An area forward is used to store auxiliary fuel tanks at the overhead, which reduces the clearance to

about 19 feet. All the way forward in hangar bay 1 some platforms and pod storage reduce the overhead clearance to about 18 feet. This overhead clearance is considerably less than in an aircraft hangar at a naval air station ashore. The division doors separating the hangar deck into three distinct bays are about 76 feet wide and are very heavy. They can be opened and closed from the Conflag Stations. From a Conflag Station, the operator can also open and close elevator doors, and activate the overhead AFFF sprinkling the AFFF flooding system in the weapons elevators. A Conflag Station is in each hangar bay and has to be manned at all times if an aircraft is in the hangar bay.



FIGURE 21. Aircraft on Hangar Deck.



FIGURE 22. Open Cockpit Canopy.



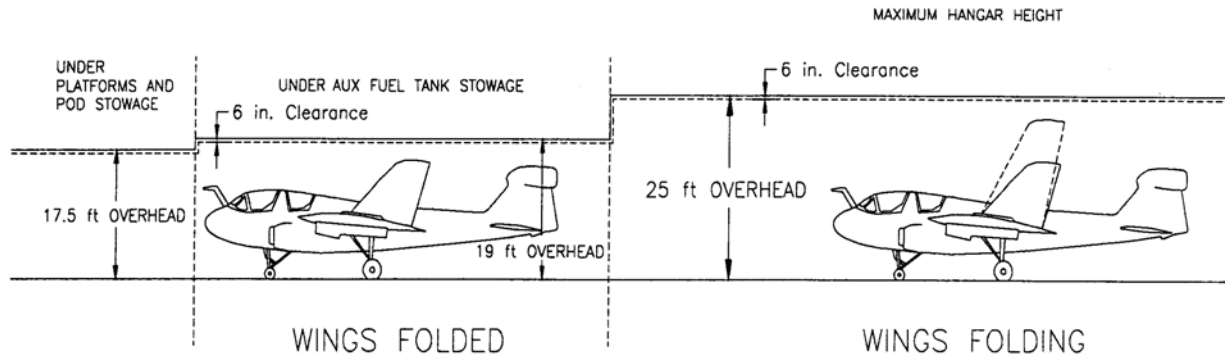


FIGURE 23. Hangar Overhead Clearance.

Figure 24, from the archives, shows one of our aircraft carriers in World War II. Note the very tight parking pattern on the flight deck. Figure 25, another archival photograph, shows what were known as “hot papas.” They wore asbestos suits and their job was to extract pilots in the event of a crash or fire on the flight deck. Those performing those duties now wear non-asbestos clothing with a highly reflective surface to minimize radiant heat effects. They usually accompany the flight deck fire truck, and their job is pilot rescue and passenger removal.



FIGURE 24. Flight Deck—World War II.





FIGURE 25. "Hot Papas."

### HAZARDOUS ENVIRONMENT

The flight deck is a fire hazardous environment for several reasons (Figure 26). Large quantities of fuel are stored in fueled aircraft, and constant fueling and defueling operations are going on. Over 3 million gallons of JP-5 (jet propellant) are stored on a *NIMITZ*-class carrier to support air operations. In addition to the fire hazard presented by the fuel, a wide variety of air-launched ordnance (missiles, bombs, and guns) are on or near the flight deck. These may be in deep storage in below-deck magazines or in temporary storage on the flight deck, on the starboard side of the island, in an area know as the "bomb farm." Ordnance is constantly being handled and moved, armed and de-armed, and may be coming aboard as part of a vertical replenishment (VERTREP) or resupply. Of course airplanes may be coming back with hung ordnance.

All of that in the midst of very high-tempo operations where everything is done in close proximity to everything else results in a volatile situation. Aircraft are being moved and constantly repotted, catapult shots and recoveries are occurring, helicopters are landing and taking off, and vehicle and people traffic is present. Fueling evolutions, ordnance handling, engines being turned up, aircraft elevators and weapons elevators constantly in motion all contribute to the confusion. A lot of little special hazards include liquid oxygen, hydraulic fluid, cartridge-actuated devices that are used to open canopies and to release weapons loads, and rocket-powered ejection seats. The wind is constantly blowing on the flight deck (most aircraft operations, launch and recovery, are into roughly 25 knots), and heavy seas and inclement weather may exist as well. Of course, from an LFT&E standpoint, you might have the enemy shooting at you.

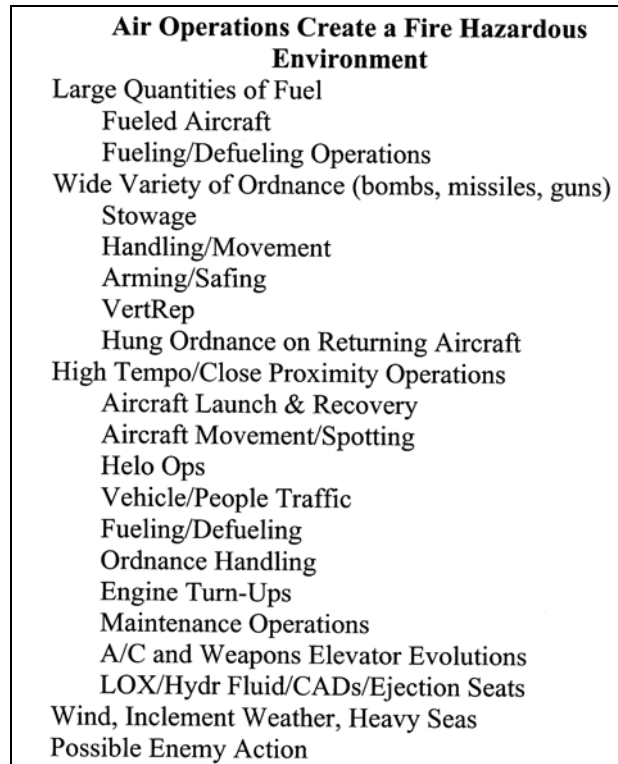


FIGURE 26. Flight Deck Hazardous Environment.

## ORDNANCE CONSIDERATIONS

Table 1 is a summary of typical air-launched ordnance that you might find on the flight deck (various missiles, bombs, rockets, mines, guns and torpedoes). Figure 27 shows the path that might be followed when moving ordnance to the flight deck from the ordnance magazines. It illustrates a major survivability decision that the Navy made many years ago to have a vertical offset in weapons elevators. Rather than having a single shaft that would provide a path of damage from the flight deck all the way down to a magazine, the elevators have to be offset, allowing for upper-stage and lower-stage elevators. The upper-stage elevators do not go any lower than the second deck, while the lower-stage elevators do not go any higher than the hangar bay. Ordnance has to be moved horizontally to get from one elevator to the next.

Weapons assembly can be done on the second deck in the crew mess room, which also doubles as a weapons-assembly area (Figure 28). Here you can see a sketch of that area. Ordnance is brought up the lower-stage weapons elevator into this area to put on items such as bomb fins. Then the ordnance would be moved over to the upper-stage weapons elevator where it could be raised to the flight deck. Weapons can be raised from the hangar deck to the flight deck using the aircraft elevators. A number of studies are underway to increase weapons-movement efficiency. One of several proposals is to have a weapons elevator that would actually be slanted so it could go outboard of the hangar bay (Figure 29). A new weapons-handling area would be added on a sponson on the 03 level. A second elevator would be used to move the

ordnance from the new weapons-handling area onto the flight deck. Again, this preserves the concept of not having a continuous path all the way from the flight deck to the magazine.

TABLE 1. Typical Air-Launched Ordnance.

Class	Name	Dimensions, in.	Weight, lb
Air-to-air missiles	Sidewinder (AIM-9L/M/R)	115.1 lg x 5.0 dia (24.9 wing span)	198.2
	Sparrow (AIM-7F/M)	152.0 lg x 8.0 dia	500
	Phoenix (AIM-54C)	156.01 lg x 15.0 dia (36.0 wing span)	1040
	AMRAAM (AIM-120)	143.9 lg x 7.0 dia (24.7 control surface span)	325.8
Air-to-surface missiles	Harm (AGM-88A)	164 lg x 10 dia (44.0 wing span)	777
	Harpoon (AGM-84D)	151 lg x 13.5 dia (36.0 wing span)	1147.5
	SLAM (AGM-84E)	175.2 lg x 13.5 dia (36.0 wing span)	1400
	Shrike (AGM-45A/B)	120.0 lg x 8.0 dia (36.0 wing span)	400
	Walleye I, II	159.0 lg x 18.0 dia (51.0 wing span)	2340
	Skipper	169.0 lg x 14.0 dia (63.0 wing span)	1280
	Maverick (AGM-65F)	97.7 lg x 12.0 dia (28.5 wing span)	669
Bombs	Mk 82 (GP); can be w/snakeye fin Mk 15, w/fin BSU-86/B and w/conical fin	91.26 lg x 11.1 dia	560-575
	Mk 83 (GP)/BLU-110/B; can be w/BSU-85B and w/conical fin	116.2 lg x 14.4 dia	985-1015
	Mk 84 (GP)	154.0 lg x 18.4 dia	2005
	Rockeye II	92.0 lg x 13.2 dia	490
Gun system	M61A1 w/LALS	N/A	319 (ammo only)
Torpedo	Mk 46	102 lg x 12.75 dia	568
	Mk 50	111.5 lg x 21.0 dia	771
Mines	Captor (Mk 60)	144.8 lg x 21.0 dia (31.2 max fin span)	2365.9
	Quickstrike (Mk 65)	128.01 lg x 20.9 dia (29.0 tail span)	2390
Rockets	5-inch in LAU-10 launcher	110.0 lg	107
	2.75-inch in LAU-69 launcher	47.85 lg	18

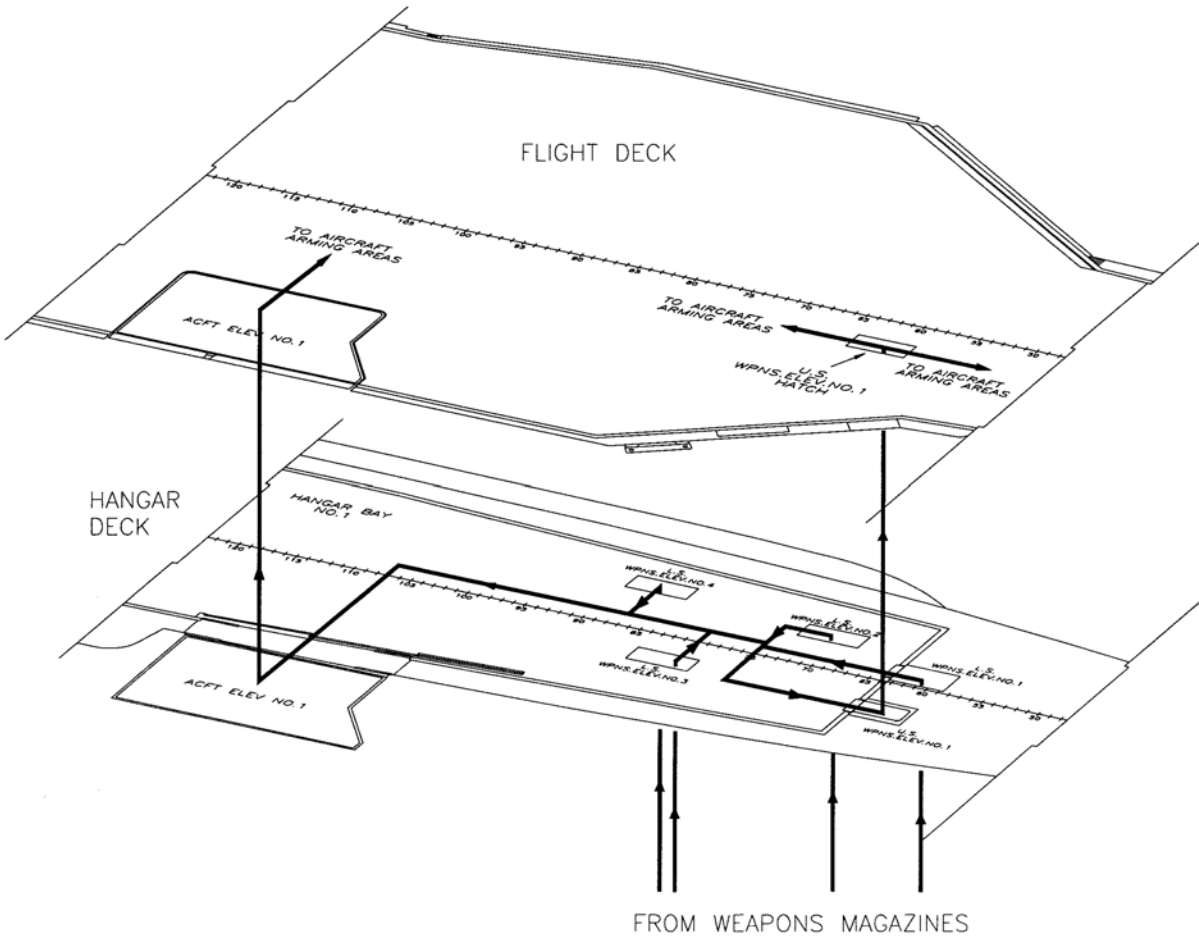


FIGURE 27. Ordnance Path of Travel.

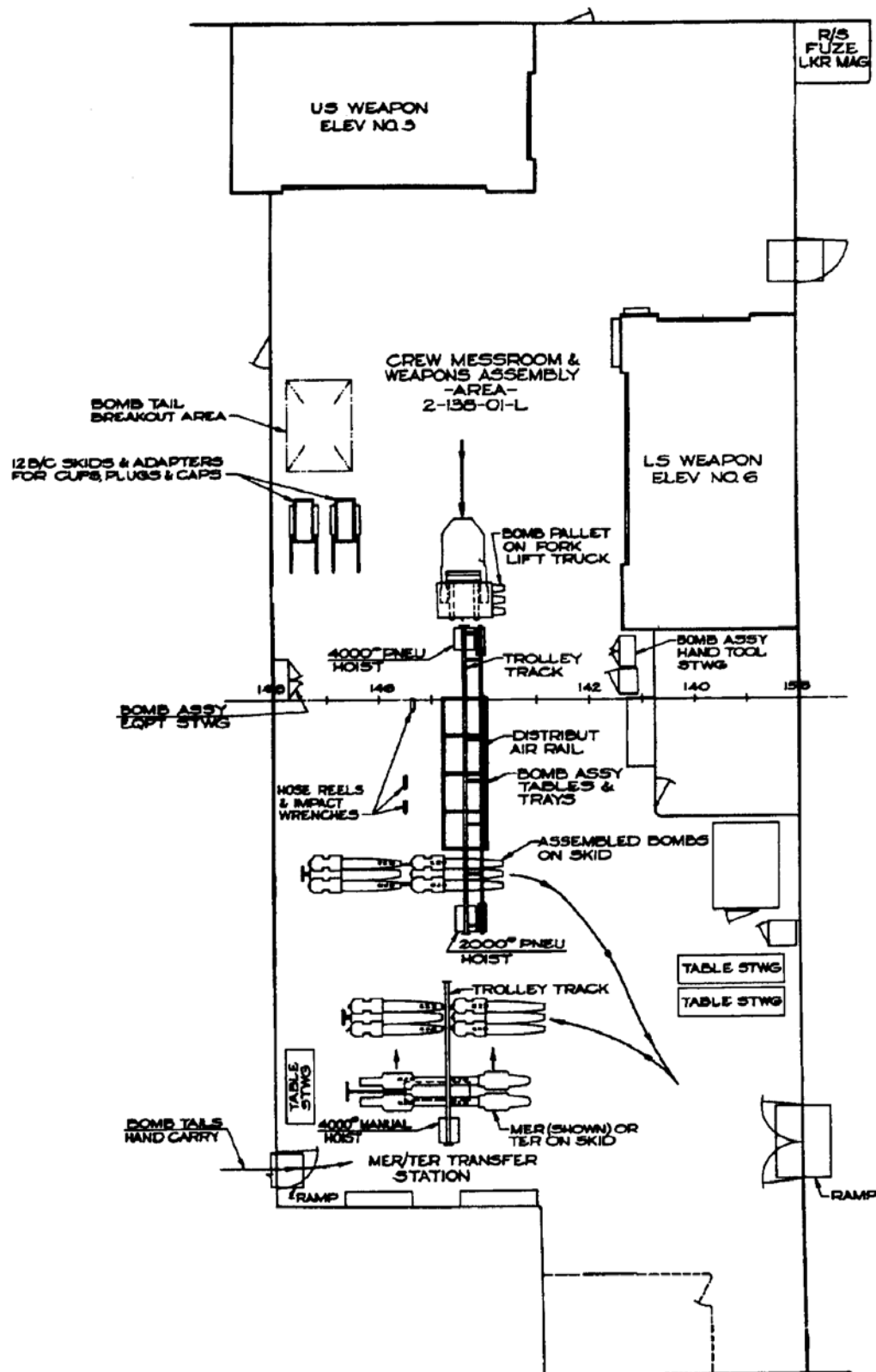


FIGURE 28. Weapons Assembly Area—Second Deck.

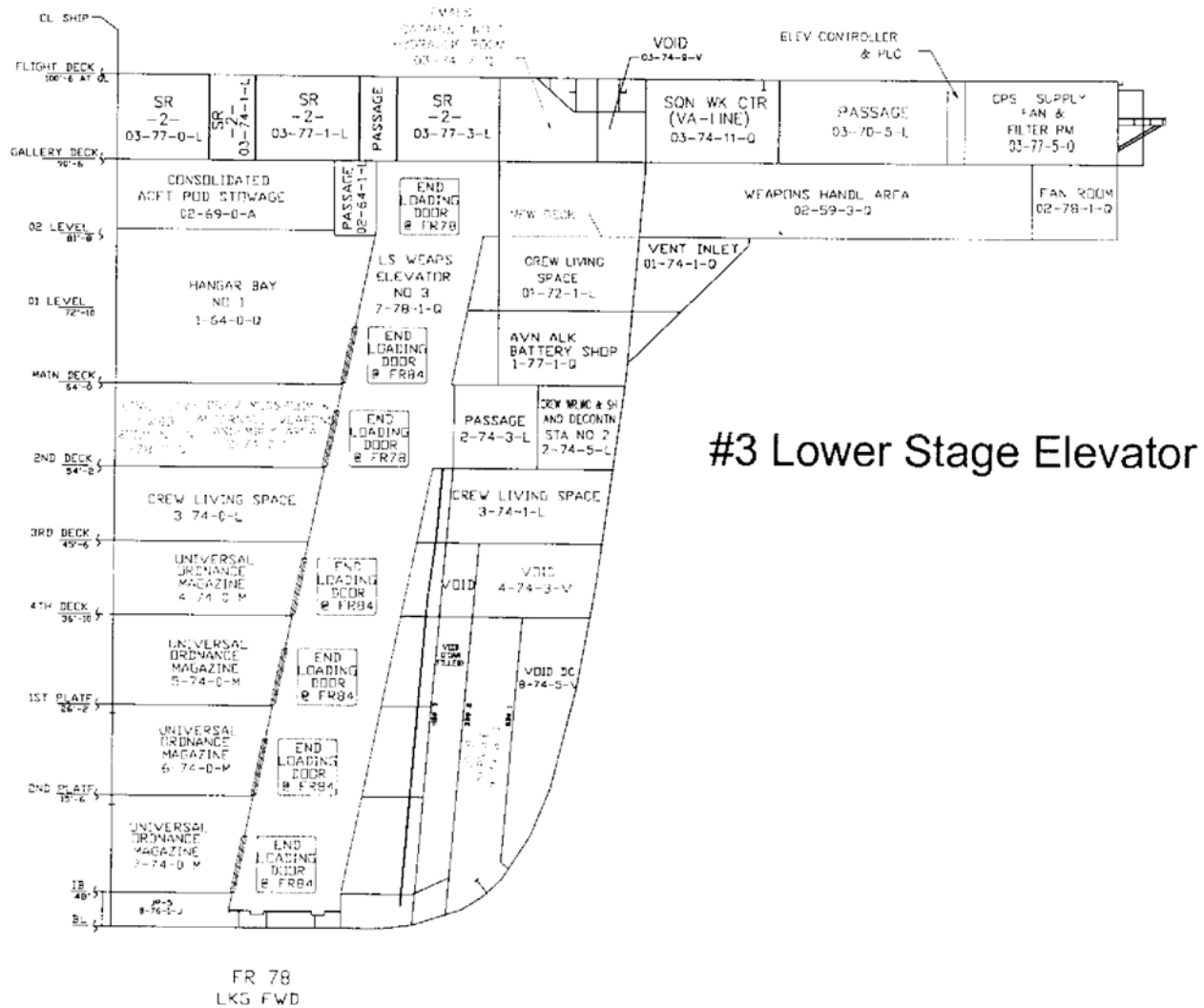


FIGURE 29. Weapons Throughput Concept.

Figures 30 through 32 show miscellaneous weapons movement evolutions on the flight deck, ordnance being moved on various skids, and missiles being temporarily stored forward of the island. Figure 33 shows how the movement of weapons can be labor-intensive evolutions. In Figure 34 they are loading bombs underneath the wings; this is a photograph of the gasoline-powered bomb hoist, which actually uses a small chain-saw motor to assist in the lift. These were significant from a fire-protection standpoint in that we had to provide Halon systems to protect the area in which they stored these gasoline-fueled hoists. Figure 35 shows the area to the starboard side of the island, known as the “bomb farm,” which does have a separate AFFF protection system. Figure 36, from the archives, shows how in World War II, as today, weapons assembly was performed in close proximity to people. The people at the top of this photograph are actually watching a movie while the people closest to the bottom of the photograph are assembling weapons.



FIGURE 30. Missile Cart.



FIGURE 31. Missile on Aircraft Elevator.



FIGURE 32. Weapons Loading on Flight Deck.



FIGURE 33. Loading Bombs.





FIGURE 34. Bomb Hoist.



FIGURE 35. Bomb Farm.



FIGURE 36. Hangar Bay—World War II.

The Insensitive Munitions (IM) Program is covered in this section (Figure 37). After the *Forrestal* disaster in 1967, the Navy formed a blue-ribbon panel, chaired by retired Admiral Russell, to look into ways to prevent a recurrence and minimize damage from flight deck fires in the future. Their top recommendation was to devise a way to keep weapons from cooking off if exposed to the heat of a fire. This became the Weapons Cookoff Program and later evolved into what is now called the Insensitive Munitions (IM) Program.

The objective is to reduce the reaction severity when ordnance is exposed to various threat stimuli. The primary fire stimuli of concern are fast and slow cookoff. In fast cookoff, a piece of ordnance is suspended above a JP-5 or JP-8 fire and immediately engulfed in flame. For slow cookoff, the piece of ordnance is in effect placed in an oven where the temperature is raised 3°C per hour. That test is to simulate exposure to a piece of ordnance while it is in deep stowage while a fire is in an adjacent compartment, or while it is being transported in a boxcar.

Other threats that have to be considered in the IM Program are bullet impact, fragment impact, shock and vibration, thermal aging, and dropping. Most ordnance has to pass a 40-foot drop test, so if a piece of ordnance is dropped during VERTREP or down an elevator shaft, you have some assurance that it is not going to react. Ordnance has to be safe from the hazards of electromagnetic radiation, which is known as the HERO program. An additional concern is sympathetic detonation, which means one piece going off causes adjacent ordnance to also detonate sympathetically. The goal of the IM program is to encourage reactions no more severe

than burning, and therefore from an IM standpoint, success is a reaction no more severe than burning. All of these test procedures are spelled out in a military standard, MIL STD 2105 B (Reference 1).

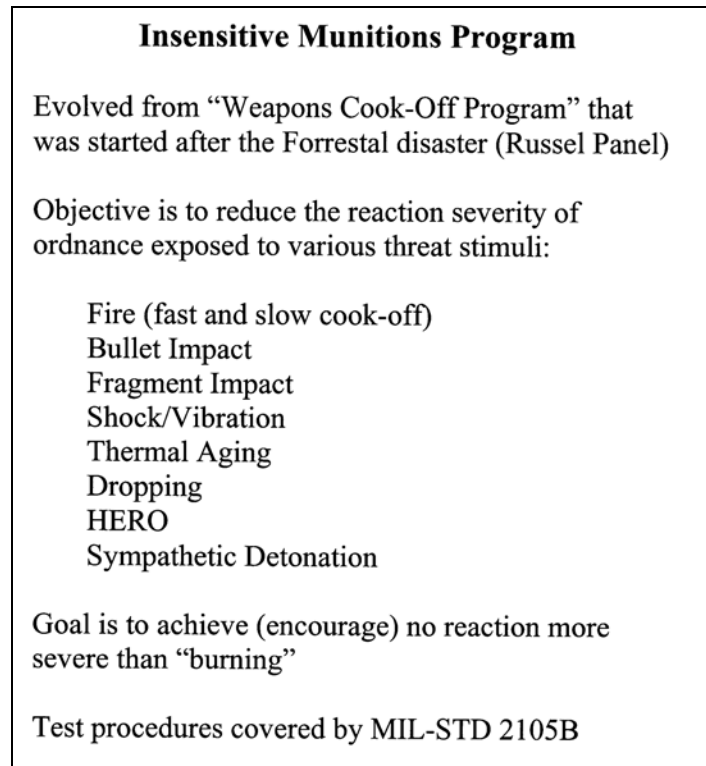


FIGURE 37. Insensitive Munitions Program.

Figure 38 describes the types of ordnance reactions and the standard definitions that have been adopted under the IM program. The worst of course is when ordnance reacts in its design mode, a detonation. At the bottom you can see the most favorable reaction, burning. Anything less than a partial detonation is unlikely to rupture the flight deck.

These definitions were significant in the *Nimitz* accident. On the *Nimitz*, ordnance deflagrated on the flight deck, but the deck was not ruptured so the event was confined to the roof. In the *Forrestal* and *Enterprise* fires, ordnance detonated with enough explosive force to blow a hole in the flight deck, which caused loss of life and considerable damage on the 03 level.

These definitions are important when referring to the possible consequences of a flight deck conflagration. One other thing concerning the burning definition is that, even with a burning reaction, firefighters may still be in jeopardy within 50 feet from the event. One of the definitions of burning is that flying debris is “not deadly beyond 15 meters.” So even with IM, firefighters must be aware of the fact that they may still be in danger if they are close to the piece of ordnance that is reacting.

<b>Types of Ordnance Reactions</b>	
<b>Detonation</b>	Most Violent Reaction
	Reacts in Design Mode
	All Energetic Material Consumed
<b>Partial Detonation</b>	Slightly Less Violent
	Some Energetic Material May Not React
<b>Explosion</b>	Violent Pressure Rupture of Case
	High Velocity Large Pieces
	Burning Material Ejected
	Unlikely to Rupture Flight Deck
<b>Deflagration</b>	Limited Fragmentation
	Minimal Blast Over-Pressure
	Burning Material Ejected
	No Rupture of Flight Deck
<b>Burning</b>	Case Opens But No Violent Fragmentation
	Localized Burning
	Generally Non-Propulsive
	Some Scattering of Debris
	Flying Debris Not Deadly Beyond 15 m (49 ft)
	Burning is Goal of IM Program

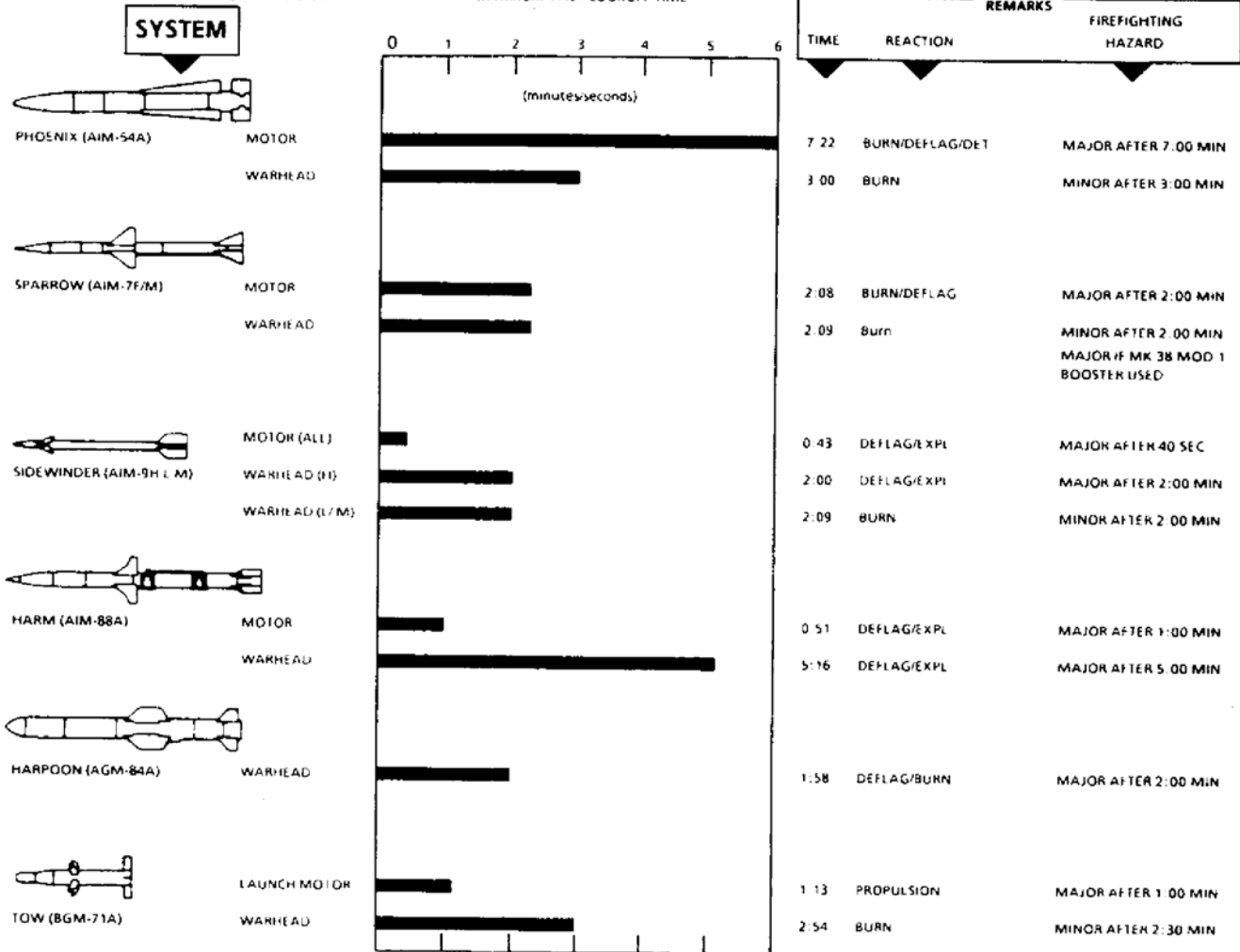
FIGURE 38. Types of Ordnance Reactions.

Figure 39 is a summary of some typical cookoff data for air-launched ordnance. Some ordnance can cook off in a couple of minutes, particularly some of the missile motors, which can react in a minute or two. Even some of the warheads can react in a couple of minutes, so speed is important. Figure 39 is a page taken out of the Naval Air Training and Operating Procedure and Standard (NATOPS) manual on aircraft firefighting (Reference 2). On some ships this would be reproduced on a pocket card and laminated. Flight-deck firefighters can carry this for ready reference to give them some idea of how long they have. Whenever ordnance is on the flight deck, an ordnance status board is required in Flight Deck Control. That board lists every piece of ordnance on the flight deck. Also an Explosive Ordnance Disposal (EOD) person is required to be in Flight Deck Control during air-ops involving ordnance. The EOD person is there to serve in an advisory capacity for incidents involving weapons.

Figure 40 shows that, if necessary, it is permissible for aircraft loaded with ordnance to be on the hangar deck. Normally you would not load or strike down ordnance on the hangar deck. However, in a wartime contingency, or in high-combat or high-tempo operations, the commanding officer can authorize the loading and strike-down of ordnance on aircraft on the hangar deck. This page is out of the CV NATOPS (Reference 3). Even with the commanding officer's authorization some restrictions still apply. Loading rockets or missiles is not allowed. (Under hangar deck in the column labeled "Load," there is NO for rockets and NO for Sidewinder, Sparrow, Phoenix.) While you cannot load missiles or rockets on the hangar deck,

you can, however, leave aircraft on a contingency basis loaded with rockets or missiles on the hangar deck for temporary stowage. That can be significant if a postulated weapons hit is being considered on a hangar bay during vulnerability assessment as a part of CVNX LFT&E.

### AIR-LAUNCHED MISSILE COOKOFF TIME SUMMARY



#### WARNING

ENSURE THAT AFFF IS CONTINUOUSLY APPLIED TO ALL WEAPONS EXPOSED TO FIRE. WATER HOSE LINES SHOULD NOT BE USED FOR ORDNANCE COOLING UNTIL AFTER THE FIRE IS EXTINGUISHED. THE USE OF WATER FOR ORDNANCE COOLING MAY DELAY EXTINGUISHMENT BY DILUTING OR WASHING AWAY THE AFFF BLANKET. POST FIRE ORDNANCE COOLING (AFFF OR WATER) SHALL CONTINUE FOR A MINIMUM OF 15 MINUTES TO ALLOW THE WEAPONS CASES TO RETURN TO SAFE AMBIENT TEMPERATURES. POST-AIRCRAFT FIRE OVERHAUL/ SALVAGE EVENTS SHALL NOT BEGIN UNTIL ALL WEAPONS HAVE BEEN DETERMINED SAFE OR REMOVED BY EXPLOSIVE ORDNANCE DISPOSAL (EOD) PERSONNEL.

#### WARNING

WEAPONS WITH SUBMUNITIONS (I.E., ROCKEYE, GATOR, TOMAHAWK BGM-109D, AND APAM), WHEN EXPOSED TO FIRE, DISBURSE UNREACTED BOMBLETS/MINES TO DISTANCES GREATER THAN 1/4 MILE. LOOSE BOMBLETS/MINES MAY BE ARMED AND ARE EXTREMELY DANGEROUS AND SHOULD BE DISPOSED OF BY EOD PERSONNEL ONLY.

FIGURE 39. Cookoff Summary (Reference 2).

## Weapons Loading/Strikedown/ Downloading and Recovery Guide

WEAPON	HANGAR DECK		RECOVERY (8)	
	LOAD	STRIKEDOWN/ DOWNLOAD	UNEXPENDED	HUNG
General Purpose Bombs/LGB/JSOW AGM-154/JDAM	YES (1) (4)	YES (5)	YES (2)	YES (2)
2.75/5.0 Rocket Launchers (all)	NO	NO	YES	NO
Aircraft Parachute Flare (LUU-2B/B)	YES (10)	YES (10)	YES	YES
Tube Loaded Flare Dispenser (Mk 45)	NO	NO	YES	YES
Tube Loaded Flare Dispenser (loaded with LUU-2B/B)	YES (10)	YES (10)	YES	YES
20-mm Guns	YES	YES (6) (11)	YES	YES
Rockeye II/Gator	YES (4)	YES (5)	YES	YES
Sidewinders (all)	NO (3)	YES	YES	YES
Sparrow III (all)	NO (3) (4)	YES (5)	YES	YES
Walleye Weapon (all)	YES (4)	YES (5)	YES (15)	YES (15)
Maverick AGM-65E/F	YES (3)	YES (5)	YES	YES
Phoenix AIM-54 (all)	NO (3)	YES (5)	YES	YES
Harpoon AGM-84/SLAM AGM-84E	NO (3) (4)	YES (5) (12) (13)	YES (12)	YES (14)
Decoy Flare (all)	NO	NO	YES	YES
Mines (all)	YES (4)	YES (5)	YES	YES
Torpedoes (all)	YES (4)	YES (5)	YES	YES
SUS Charge (Mk 64)	YES	YES	YES	YES
Marine Marker (all)	YES	YES	YES	YES
TALD	YES	YES	YES	YES
Practice Bombs (all)	YES (4)	YES (5)	YES	YES
JAU-1B and JAU-22/B Cartridge	YES	YES (8) (9)	YES	YES
25-mm Gun GAU-12	YES	YES (11)	YES	YES
Harm AGM-88A	NO (3)	YES (5)	YES	YES
Chaff (w/cartridge)	YES	YES	YES	YES
GBU-24	YES (4)	YES (5)	NO (7)	NO (7)

**Notes:**

1. No mechanical nose fuzes will be installed on the hangar deck.
2. Arming wires/safety clips intact.
3. Air-launched missiles shall not normally be loaded on the hangar deck except when operational commitments so dictate. Commanding officers may authorize loading of missiles on the hangar deck only up to the point of mechanical attachment of the weapon to the launcher/rack in accordance with the procedures prescribed in the appropriate NAVAIR weapon/store loading checklists.
4. Ejector cartridges shall not be installed on the hangar deck. Installation of ejector/jettison cartridges in the BRU-9/-10/-11 ejector bomb rack is authorized provided the rack is electrically disconnected and either the mechanical safety pin is installed or the IFOBRL mechanism is locked.

FIGURE 40. Weapons Loading/Strikedown Guide (Reference 3).

5. In the event of strikedown of a loaded aircraft to the hangar deck, the nose fuzes (as applicable) and ejector/jettison cartridges shall be removed immediately after the aircraft is in spot and tied down. Ejector/jettison cartridges may remain in the BRU-9/-10/-11 ejector bomb rack provided the rack is electrically disconnected and either the mechanical safety pin is installed or the IFOBRL mechanism is locked.

6. The M61A1 gun ammunition is exempt from downloading requirements for up aircraft temporarily spotted in the hangar decks and aircraft undergoing limited maintenance; that is, turnaround maintenance, providing compliance with all gun dearm procedures of the airborne weapon/store loading manual, associated checklists, and store reliability card has been accomplished.

7. Guidance provided in the appendix is subjected to individual aircraft tactical manual limitations.

8. Maintenance on loaded aircraft (see Chapter 6 of this manual) applies.

9. Sonobuoy chutes P-2 shall be downloaded immediately after aircraft is in spot and tied down.

10. Impulse cartridges must be removed for LUU-2 and dispenser with LLU-2.

11. Strikedown/download of aircraft with jammed 20-mm/25-mm guns and gun pods is prohibited.

12. If an ITL signal has been initiated for a Harpoon/SLAM weapon, that weapon shall be treated as a hung weapon during recovery, downloading, and strikedown aboard ship.

13. An aircraft with ITL weapons aboard shall not be removed from the flight deck to the hangar deck until all ITL weapons have been downloaded.

14. When operationally feasible, aircraft shall be kept airborne for 35 minutes following an ITL abort/failure. Respot of an ITL aircraft is prohibited during peacetime operations until 2.5 hours have elapsed after the ITL abort/failure. Download prior to completion of the 2.5-hour waiting period is authorized provided that the missile is moved to a safe area on the flight deck with the nose oriented outboard over the deckedge.

### WARNING

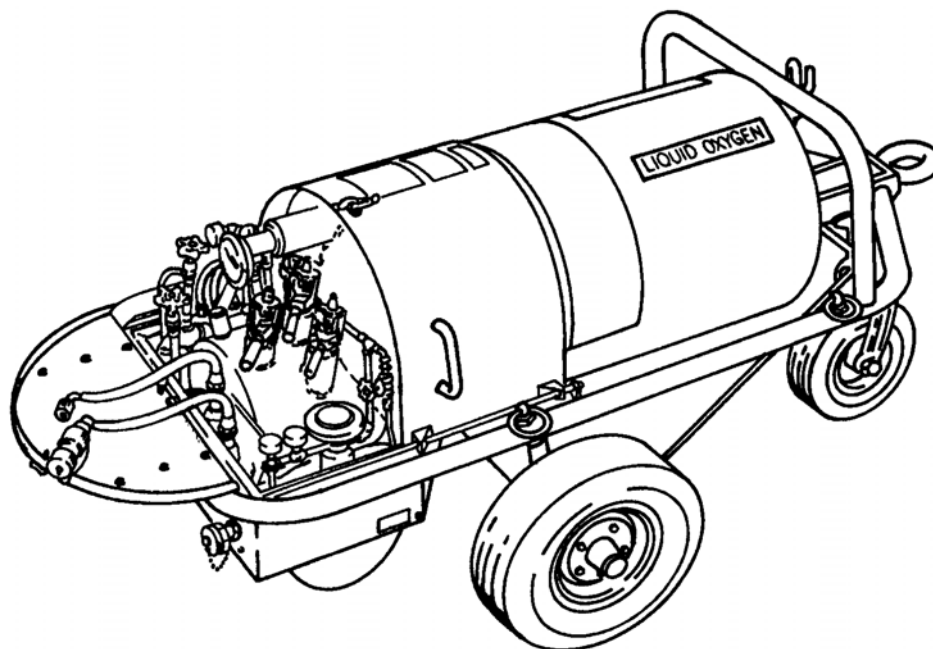
Initiation of the ITL signal activates a battery within Harpoon/SLAM. With battery power available within the missile, electrical shorts occurring during aircraft recovery and/or while disconnecting the missile umbilical from the aircraft may actuate the missile engine/pyrotechnics. Battery voltage will remain sufficiently high to allow engine start for up to 35 minutes following ITL and to fire missile launch squibs within Harpoon/SLAM for up to 2.5 hours following ITL.

15. Walleye II loaded on F/A-18 is nonrecoverable.

FIGURE 40. (Contd.).

## FUEL AND MISCELLANEOUS HAZARDS

Figure 41 shows one of the miscellaneous hazards—a liquid oxygen storage tank (Reference 4). Table 2 illustrates how many JP-5 fueling stations are around the flight and hangar decks. The hangar deck would be used only in a special case. Most of the fueling and defueling is done on the flight deck. Anywhere from 14 to 18 JP-5 fueling stations are on the flight deck. Also about six or seven fueling stations are located on the hangar deck.



LIQUID OXYGEN STORAGE TANK , TMU 70/M

The Liquid Oxygen Storage Tank, TMU 70/M, is a completely self-contained unit comprised of three (3) major components: a 50- gallon DEWAR storage tank, a 15- liter DEWAR transfer tank, and a system of transfer lines and control valves. The three (3) components are permanently mounted on a portable 3- wheel trailer equipped with a manually operated parking brake system and retractable caster wheel. The storage and transfer tanks are equipped with liquid level and pressure gages, and pressure relief devices. The primary purpose of this equipment is the servicing of aircraft liquid oxygen converters. It is used only for the storage of liquid oxygen conforming to Type II Specification MIL-O-27210. The transfer lines carry the liquid oxygen from the storage tank to the transfer tank and then to the converter. The transfer lines also carry the vented oxygen gas from the converter back to the storage tank. The closed loop of the transfer lines contains the vented oxygen gas to avoid venting large volumes of gas during converter filling operations. The interconnecting liquid and return gas lines are

vacuum jacketed transfer lines wherever practical. These lines are of minimum length to reduce cool-down and heat leak losses.

Reference Manual: NAVAIR 19-25D-26  
NSN: 6RX 3655-00-158-0657-SX7X  
PN: 22455

#### LEADING PARTICULARS

LENGTH	90 in.
WIDTH	48 in.
HEIGHT	36 in.
EMPTY WEIGHT	616 lbs.
LOADED WEIGHT	1091lbs.
<u>WORKING PRESSURE:</u>	
STORAGE TANK	50 psig
TRANSFER TANK	90 psig
<u>RELIEF VALVE SETTINGS:</u>	
STORAGE TANK VENT LINE	50 psig
FILL LINE	75 psig
TRANSFER TANK VENT LINE	90 psig
<u>SAFETY DEVICE BURST PRESSURE:</u>	
STORAGE TANK	75 psig
TRANSFER TANK	120 psig

FIGURE 41. Liquid Oxygen Cart.



TABLE 2. JP-5 Fueling Stations.

Hull no.	Ship name	Ship class	JP-5 fuel service			
			Flight deck outlets	Hangar deck outlets	Hoses per outlet - 2.5-inch hose	Defueling capacity per outlet/portable hose, gpm
CVN-76	<i>Ronald Reagan</i>	68	14	7	2 flight deck (6 w/3; 3 w/4) 2 hangar deck	100/75
CVN-75	<i>Harry S. Truman</i>	68	14	7	2 flight deck (6 w/3; 3 w/4) 2 hangar deck	100/75
CVN-74	<i>John C. Stennis</i>	68	14	7	2 flight deck (6 w/3; 3 w/4) 2 hangar deck	100/75
CVN-73	<i>George Washington</i>	68	14	7	2 flight deck (6 w/3; 3 w/4) 2 hangar deck	100/75
CVN-72	<i>Abraham Lincoln</i>	68	14	6	2 flight deck (6 w/3; 3 w/4) 2 hangar deck	100/75
CVN-71	<i>Theodore Roosevelt</i>	68	14	6	2 flight deck (6 w/3; 3 w/4) 2 hangar deck	100/75
CVN-70	<i>Carl Vinson</i>	68	14	6	2 flight deck (6 w/3; 3 w/4) 2 hangar deck	100/75
CVN-69	<i>Dwight D. Eisenhower</i>	68	14	7	2 flight deck (5 w/3; 5 w/4) 2 hangar deck	100/25
CVN-68	<i>Chester W. Nimitz</i>	68	14	6	2 flight deck (5 w/3; 2 w/4) 2 hangar deck	100/50
CVN-67	<i>John F. Kennedy</i>	63/67	18	7	4 flight deck (1 w/6) 2 hangar deck	100/80
CVN-65	<i>Enterprise</i>	65	17	7	4 flight deck (5 w/2; 2 w/3) 2 hangar deck (1 w/3)	100/25
CV-64	<i>Constellation</i>	63/67	14	6	4 flight deck (7 w/3) 2 hangar deck (2 w/1)	100/25
CV-63	<i>Kitty Hawk</i>	63/67	15	6	4 flight deck (1 w/3) 2 hangar deck	100/25

Figure 42 lists the four primary fuels used to fuel military aircraft during the last 20 years. Most piston aircraft are fueled with aviation gasoline, which is very similar to motor gasoline and the most hazardous of the aviation fuels. JP-4, which is an analog to commercial Jet B, was once the standard fuel for U.S. Air Force aircraft. The Air Force converted to JP-8, as has the Navy for shore-based aircraft. JP-8 is identical to the standard fuel used for commercial aircraft, commonly called commercial Jet-A1.

JP-8 has a flashpoint of 100°F minimum. Flashpoint is defined as the lowest temperature at which a fuel gives off sufficient vapors to be ignited—a vaporization temperature. It is not an ignition temperature but the temperature at which vapors will start to form in sufficient quantities so that with a source of ignition those vapors would ignite. JP-5, which is the safest of all aviation fuels and has the highest flashpoint, is bought under a very rigid military specification. The flashpoint is not allowed to be less than 140°F.

<b>Aviation Fuel Issues</b>	
<u>Fuel</u>	<u>Flash Point</u>
AvGas	< 10 ° F
JP-4 (Comm Jet B)	0-10 ° F
JP-8 (Comm Jet A-1)	100 ° F min
JP-5	140 ° F min
<u>NRL Report of April 1992:</u> (JP-5 Vs JP-8)	
Real concern is fuel spill in hot climate.	
Summer flight deck surface temperatures: 140-190 °F	
Around steam catapults: 200 ° F +	
NRL Assessed:	
Ease of Ignition:(50/50 Mixture Flash Point = 115°F)	
Flame Spread Speed: (JP-8 = 2 x JP-5)	
Extinguishment Difficulty: 1 Hoseline for JP-5	
2 Hoselines for JP-8	

FIGURE 42. Aviation Fuel Issues.

The Navy restricts carrier operations to the use of JP-5. In other words, while JP-8 is acceptable for fueling aircraft at a Navy air station, it is not used to fuel aircraft on an aircraft carrier. Restrictions apply should an airplane containing JP-8 be brought aboard. Should an aircraft be fueled at an air station or perhaps during a mid-air refueling evolution and then land on a flight deck, it will have a lower flashpoint than is normally permissible on the flight deck. Accordingly, certain restrictions apply in such a case.

Concern was expressed in the early 1990s when the Navy was being pressured to adopt JP-8 as a standard fuel for all jet aircraft applications—the same as the Air Force and Navy ashore. So the Naval Research Laboratory (NRL) did a study in 1992 to quantify the difference in fire threat between JP-5 and JP-8. The real concern is operation in a hot climate where fuel might be heated either because of hot flight deck temperatures or because the aircraft is sitting out in the sun and the fuel in the aircraft tanks is heating up. The Atlantic Fleet (AIRLANT) reported that summer flight deck surface temperatures could get as hot as 190°F, and around the steam catapults the metal temperatures can reach well over 200°F.

The question was if preheated fuel or fuel heated by the sun spilled onto a hot deck, what would the difference be between JP-5 and JP-8? NRL looked at the ease of ignition, the flame spread rate (how fast the flame front moves across the surface of spilled fuel), and ease of extinguishment. They found that very little JP-8 added to JP-5 would drop the flashpoint. In fact at a 50/50 mixture, the flashpoint of JP-5 would be reduced from 140°F to 115°F. They also found that the flame-spread rate for JP-8 is about twice that of JP-5. In other words, with JP-5

you could walk away from it if it was ignited, but with JP-8 you had better be running because it would burn across the surface of the fuel twice as fast.

NRL also found that for the threshold extinguishment capability of a single hoseline for fires involving JP-5, what could be put out with one hoseline would require two hoselines if it were JP-8. So a measurable difference exists in fire safety between the two fuels. Therefore, the Navy has adopted restrictions on the use of JP-8 (Figure 43) as delineated in NAVAIR 00-80T-109, the aircraft refueling Naval Air Training and Operating Procedures Standardization (Reference 5) and a companion publication (Reference 3). The current restrictions are summarized on the bottom of Figure 43. Essentially, aircraft with a flashpoint of less than 120°F shall not be parked in the hangar bay. A fuel sample may be required for a flashpoint test, which can be done on carriers. If the flashpoint is less than 120°F, the aircraft cannot be moved from the flight deck to the hangar deck. If the flashpoint is between 120 and 140°F, the aircraft can be moved to the hangar bay, with the personal approval of the Commanding Officer, provided all the sprinkler groups are operational, all of the Conflag Stations are manned, and any hotwork in the hangar bay is curtailed.

Current Restrictions on JP-8
Per:
NAVAIR 00-80T-109 (A/C Refueling NATOPS)
NAVAIR 00-80T-105 (CV NATOPS)
A/C with fuel flash point < 120° F shall not be parked in the hangar bay.
If flash point 120-140° F, aircraft may be parked in hangar bay provided:
CO approves
All sprinkler groups are operational
Conflag stations manned
No hotwork in the bay

FIGURE 43. Restrictions on JP-8.

## TYPES OF FIRES

In Figure 44 the list of ignition sources on a typical flight deck includes hot engines, the exhaust from engines, yellow gear (aviation support equipment), exhaust from starting carts. The exhaust from a gas turbine starting cart caused the fire on the *Enterprise*. Electrical arcing and sparking potential exist as might cutting and welding, static discharges, electromagnetic radiation, catapult steam lines, aircraft crashes, firing of ordnance, or arson/terrorist. We have been fortunate that we have not had such an incident on the flight deck. During the Vietnam War some very unsavory things were dropped from bridges, such as the Golden Gate Bridge in San Francisco, as the ships were leaving. There was concern that war protestors might dump incendiary devices on the flight deck, but fortunately that never happened. The real concern is that in combat the ignition source may be provided by enemy action.

Ignition Sources on Flight Deck	
Hot Engines	
Engine Exhaust	
Yellow Gear	
Exhaust from Starting Carts	
Electrical Arcing and Sparking	
Cutting and Welding	
Static Discharges	
Electromagnetic Radiation	
Catapult Steam Lines	
Aircraft Crashes	
Ordnance Inadvertent Firings	
Arson/Terrorist	
Enemy Action	

FIGURE 44. Ignition Sources.

Figure 45 is an attempt to illustrate the various types of potential fires, i.e., fires in engines and engine nacelles, fires involving spilled fuel on the flight deck, miscellaneous electrical fires internal to aircraft, catapult track fires (catapult tracks are protected by a steam smothering system). Fires may originate external to the flight or hangar deck. Examples include the *Belknap/Kennedy* collision when a cruiser was burning underneath the angle deck and the flames reached above the flight deck. An example of fire on the hangar deck is the motor gasoline fire on a sponson of the *George Washington*, which threatened the hangar deck. Fires can burn the energetic fill in ordnance or pyrotechnics. Aircraft crashes that produced large pool and three-dimensional fires and fires threatening ordnance have proven to be the worst case based on past experience.

In spite of the hazardous nature of flight operations, our safety record fortunately has been very good (Figure 46). All evolutions are well orchestrated, frequently practiced, and constantly and competently supervised. Strict procedures are in place, safety rules and regulations are rigidly enforced, and training and readiness are constantly emphasized. Additionally, lessons learned from past accidents are continuously incorporated into systems, tactics, and procedures.

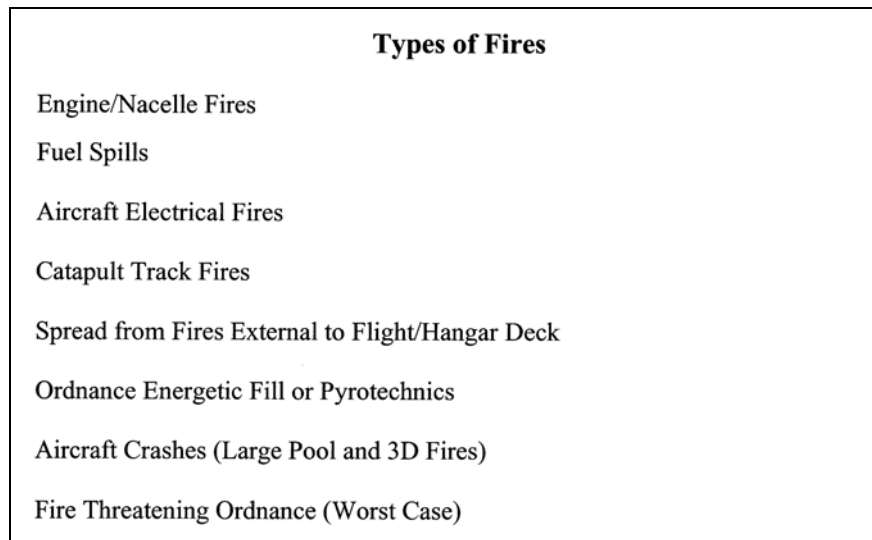


FIGURE 45. Types of Fires.

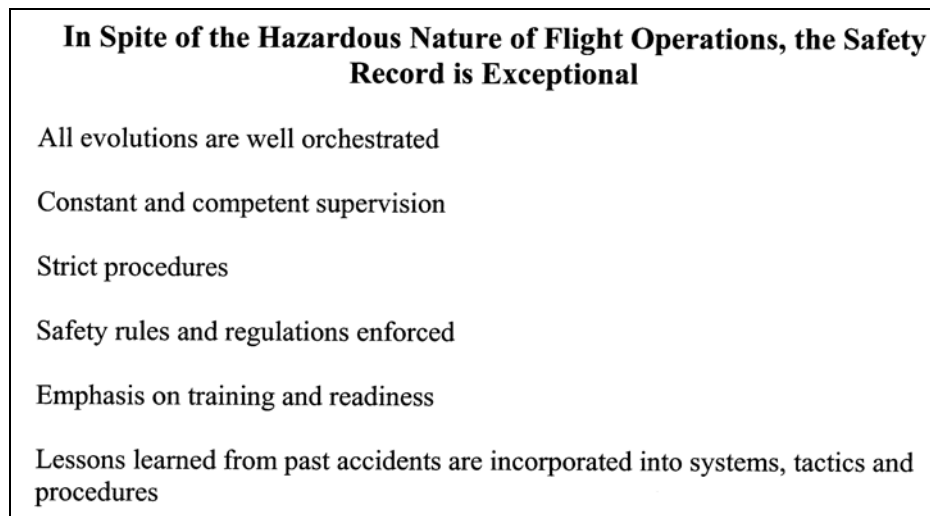


FIGURE 46. Safety Record is Exceptional.

## **FIREFIGHTING AGENTS**

Firefighting agents are listed in Figure 47. The most prevalent agent, and the one on which we are the most reliant, is AFFF. AFFF was originally called "Light Water" when introduced in the Navy in the 1960s. AFFF works by causing an aqueous film to float on the top surface of fuel. Because of the difference in specific gravity between a flammable liquid and water, water normally settles to the bottom and the fuel floats on top. The film formation is caused by surface-tension effects created by the fluorocarbon surfactants that are contained in AFFF.

<b>Fire Fighting Agents</b>
Aqueous Film Forming Foam (AFFF)
Potassium Bicarbonate Powder (PKP – aka “Purple K”)
Carbon Dioxide (CO <sub>2</sub> )
Halon 1211
Seawater
Freshwater
Steam

FIGURE 47. Firefighting Agents.

The Navy converted to AFFF from protein foam at air stations in the 1960s and aboard ship in the 1970s. The big impetus for that change in aircraft carriers of course was the fires on the *Forrestal* and *Enterprise*. Compared to protein foam, AFFF will put the fire out with about one-third the application rate. In other words, on a gallon-for-gallon basis, AFFF will put the fire out three times as fast with only one-third as much agent. The patent on AFFF is held by the Navy. Since its adoption by the Navy, it has become the standard foam agent in the Air Force, Army, Coast Guard, Marine Corps, and most foreign military services. AFFF is now the primary agent at almost all civilian airports in the United States. In a survey of the 25 largest airports in the U.S., 80% were using AFFF that is procured to the U.S. military specification. However, a potential problem now involves AFFF—an emerging environmental issue that could have future ramifications.

Dry chemicals are used to fight three-dimensional and running-fuel fires. The Navy has standardized on potassium bicarbonate, which is more effective than the old baking soda type (sodium bicarbonate). To distinguish potassium bicarbonate from sodium bicarbonate, it is traditionally dyed purple, and that is where the name purple K powder (PKP) comes from. PKP is usually carried in portable extinguishers, and carbon dioxide is carried in portable extinguishers around the flight deck and hanging deck. We carry Halon 1211 on portables on the P-25 crash truck on the flight deck.

Seawater hose stations in addition to AFFF hose stations are around the flight deck. Fresh water is carried in portable extinguishers in the “crash and smash locker” in the island. The fresh water is carried primarily to freeze leaks in lox bottles, and steam is also used as an extinguishing agent for fires in catapult troughs. A diverter valve diverts steam from the main catapult launch valve. The steam is diverted so it can flood the catapult trough or the main valve enclosure room. Steam is used because it is available to power the catapults.

Questions raised about future conversions from steam catapults to EMALs include the following: since steam will no longer be available, how will we extinguish fires in catapult



troughs? Steam is usually the source of ignition because the hot steam piping is what ignites the fuel spilled into the catapult trough. EMALs may not serve as a source of ignition the same as the steam catapults. A hazard assessment of the EMALs is needed to see if any fire threat exists and if so the best way to counter that threat.

## **FIREFIGHTING SYSTEMS AND EQUIPMENT**

Firefighting systems available on the flight deck are listed in Figure 48. The entire flight deck is protected by an AFFF washdown system. On a *Nimitz*-class carrier the washdown system would be divided into 20 zones, and each zone delivers nominally 1000 gallons per minute of AFFF solution. AFFF is discharged primarily through flush-deck nozzles that are mounted in the deck. Hundreds of these nozzles on a *Nimitz*-class carrier deliver AFFF at an application rate of 0.06 gallons per minute per square foot (gpm/ft<sup>2</sup>) of flight deck area. These are augmented by deck-edge nozzles, mounted on the port and starboard side, which shoot through the coaming or over the coaming. These nozzles spray inboard to protect the high-density parking areas near the edge of the deck and also where aircraft are fueled and defueled. Deck-edge nozzles are designed to provide an additional 0.08 gpm/ft<sup>2</sup> of deck area within about 50 feet of the deck edge. The AFFF washdown system can be activated from control panels located in Primary Flight Control (Pri-Fly) and the Navigation Bridge.

Each aircraft elevator is protected by four nozzles that spray directly onto the elevators at 40 gpm each. In addition, a separate AFFF delivery system protects each upper-stage weapons elevator that terminates on the flight deck. Three nozzles in each shaft (two at the top and one at the bottom), which can deluge the shaft with AFFF, can be activated from the catwalks or in the Conflag Stations.

The bomb farm on the starboard side of the island has a dedicated AFFF system consisting of two outboard nozzles every 8 feet. That system protects against any sort of fuel spill that might jeopardize the bomb farm. The bomb farm system can be activated from controls mounted on the island or in Flight Deck Control, and on some ships it can be activated from the AFFF panel in Pri-Fly and the Navigation (NAV) Bridge. NAVAIR provides a little mobile firefighting vehicle (MFFV) called the P-25, located on all flight decks.

Hose stations are located around the entire flight deck on both sides, at 22 locations. AFFF is delivered to both 1.5-inch hose reels and 2.5-inch soft hoses that are mounted on a rack. The advantage of the 1.5-inch hose reels is that they have a flow-through feature. If only 20 feet of hose is needed, rather than having to take all the hose out of the rack, 20 feet can be pulled off of the reel. The AFFF flows through the hose that remains on the reel, so one person can readily put it in operation. Seawater hose stations are at many locations, and at every hose station are both a CO<sub>2</sub> and a PKP portable.

Catapult troughs are protected by steam-smothering systems. Bomb-jettison chutes around the flight deck allow rapid disposal of a bomb by rolling it over and down the chute. Additionally, many aircraft have their own onboard extinguishing system to protect their engine nacelles and dry bays. Normally, those would not be activated for a fire on the flight deck.

However, if the fire is internal to the aircraft and someone is in the aircraft, that person could trip the onboard extinguishing system.

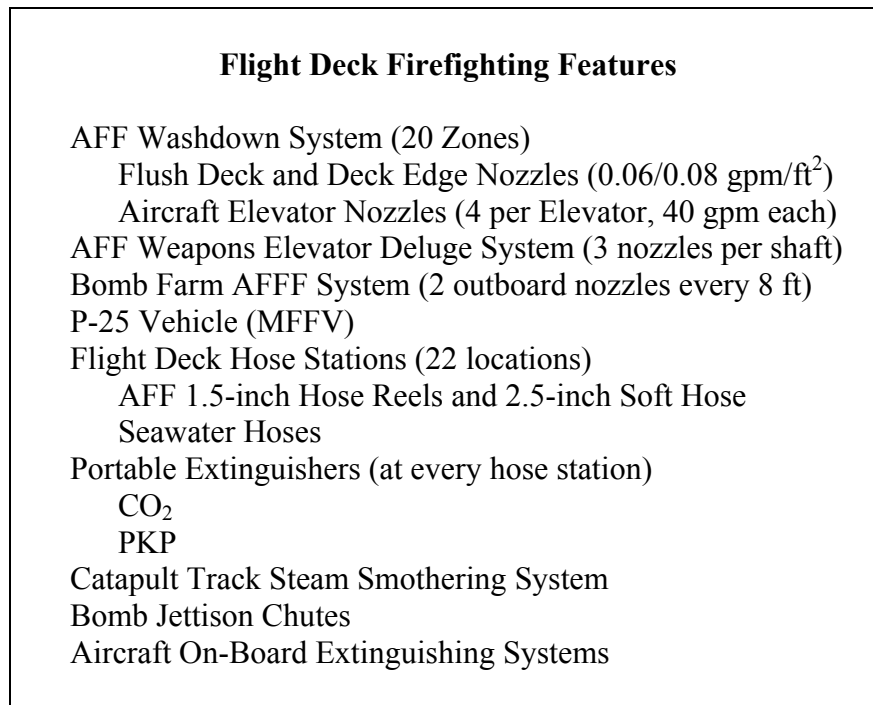


FIGURE 50. Firefighting Features—Flight Deck.

The hangar deck (Figure 49) is similarly protected by AFFF overhead sprinkling. Before the *Forrestal*-class hangar bay sprinklers were designed to discharge only water. Foam coverage was provided by large manually aimed foam monitor nozzles mounted on each side of the hangar. The *Forrestal* was the first ship built with overhead hangar foam sprinkling (protein foam in those days). As carriers converted to AFFF in the 1970s, existing protein-foam sprinklers converted to AFFF. The *Nimitz* was the first carrier to have hangar AFFF sprinkling built in during construction. Fourteen groups were designed to discharge at an application rate of 0.16 gpm/ft<sup>2</sup>. This application rate is much higher than the flush-deck system. This system was designed to compensate for the shadow effect caused by the fuselage and wings, which hamper the delivery of AFFF from the sprinklers to the floor of the hangar bay. Throughout the three hangar bays are 14 AFFF hose stations and two additional hose stations on the fantail. Same as on the flight deck, portable extinguishers are near every hose station. Each hangar bay has a Conflag Station where a man is constantly on watch whenever aircraft are located on the hangar bay. The bays can be divided by the division doors; elevator doors can be closed remotely to keep a fire on an aircraft elevator from spreading into the hangar and vice versa. AFFF deluge systems are in the lower stage weapons elevators that terminate on the hangar deck.

<b>Hangar Deck Firefighting Features</b>
Overhead AFFF Sprinkling (14 Groups, 0.16 gpm/ft <sup>2</sup> )
Fantail AFFF Sprinkling
AFFF Hose Stations (14 in. Hangar, 2 on Fantail)
Portable Extinguishers
Conflag Stations (One per Bay)
Division and Elevator Doors
Twin-Agent Unit (TAU)
AFFF Weapons Elevator Deluge System

FIGURE 49. Firefighting Features—Hangar Deck.

As shown in Figure 50, AFFF for the flight and hangar deck is supplied by 20 high-capacity fog-foam (HCFF) stations located on the second deck. These stations have the injection pumps and proportioners that provide AFFF to all of the demand points—washdown system, bomb farm system, AFFF hoses, weapon elevators, and hangar sprinklers. Each HCFF station contains a 600-gallon tank of AFFF concentrate. The Navy uses 6% AFFF aboard ships, that is, six parts concentrate to 94 parts sea water. In addition to the 20 600-gallon tanks are two 3,500-gallon AFFF reserve storage tanks. Each carrier has a hard piped tank-to-tank transfer system so AFFF can be pumped from one HCFF station to another or to and from reserve tanks. Each aircraft carrier carries roughly 20,000 gallons of AFFF concentrate. Most of the concentrate is in those 600- or 3,500-gallon tanks and a few extra cans, which are carried for re-supply. Additionally a few cans are carried in repair stations for use by AFFF portable in-line eductors.

### **AFFF Supply and Proportioning**

All Flight/Hangar Deck AFFF demands are supplied from high-capacity proportioning stations (HCFFs) on the Second Deck.

#### 20 HCFF Stations Total per *Nimitz*-Class Carrier

Each HCFF has an AFFF injection pump to supply AFFF washdown and Bomb Farm System and a balanced pressure proportioner to feed AFFF hoses, weapons elevators, and hangar sprinklers.

Each HCFF contains a 600-gallon tank of AFFF concentrate (designed for 6% proportioning: 6 parts concentrate to 94 parts seawater).

In addition, there are two 3500-gallon AFFF reserve stowage tanks.

AFFF concentrate may be pumped from HCFF to HCFF and to/from reserve tanks by a hard piped tank-to-tank transfer system.

Each carrier has over 20,000 gallons of AFFF concentrate.

FIGURE 50. AFFF Supply and Proportioning.

The photograph in Figure 51 was taken during the acceptance trials on *Harry S. Truman*. The Board of Inspection and Survey (INSURV) normally likes to see the entire flight deck lit off with AFFF. The photograph shows that the ship does have enough capacity to activate the entire flight deck. A *Nimitz*-class carrier will have the ability to pump 27,000 gpm of water, which is enough, assuming all the pumps are operational, to distribute AFFF over the entire flight deck. Normally you would not trip the entire system. Under current guidance you are supposed to trip the AFFF system in the zone in which the fire is located and in the upwind zone. We found that the upwind zone actually contributes the most to fire extinguishment because, with the normal wind over the deck during flight evolutions, the wind tends to push the AFFF as a squeegee would, rapidly spreading the AFFF over the fire.



FIGURE 51. Flush-Deck-System Operation.

Figure 52 is another view of an AFFF system test on a carrier. The deck-edge nozzles that shoot inboard have been activated in this photograph. A requirement calls for the periodic discharge of AFFF onto the flight deck and an analysis of a sample to be sure that the proper ratio exists between seawater and AFFF concentrate. Figure 53 is a photograph of one of those tests, typically run on an overhaul cycle basis. This shows a person using a cup to collect a sample of AFFF for analysis. Figure 54 is a drawing of the standard flush-deck AFFF nozzle (which delivers about 30 gpm at 30 pounds per square inch (psi)). The only moving part is a ball in the throat that moves off of the seat when AFFF is flowing and then rolls back into the seat to keep debris out of the throat of the nozzle.

Underneath most of the nozzles, clean-out plugs have been added to enable a plugged nozzle to be cleaned from below (Figure 55). Now that most ships put on covers when they go into port, the need for the clean-outs has been considerably reduced. Covers should be in place when the nonskid is being removed or applied. In Figure 56, to the lower left, the deck-edge nozzles are discharging above the coaming to provide protection near the edge of the deck. Figure 57 is another view of the nozzles shooting above the gutter onto the flight deck.



FIGURE 52. Flush-Deck and Deck-Edge System Operation.



FIGURE 53. Flush-Deck System Test.



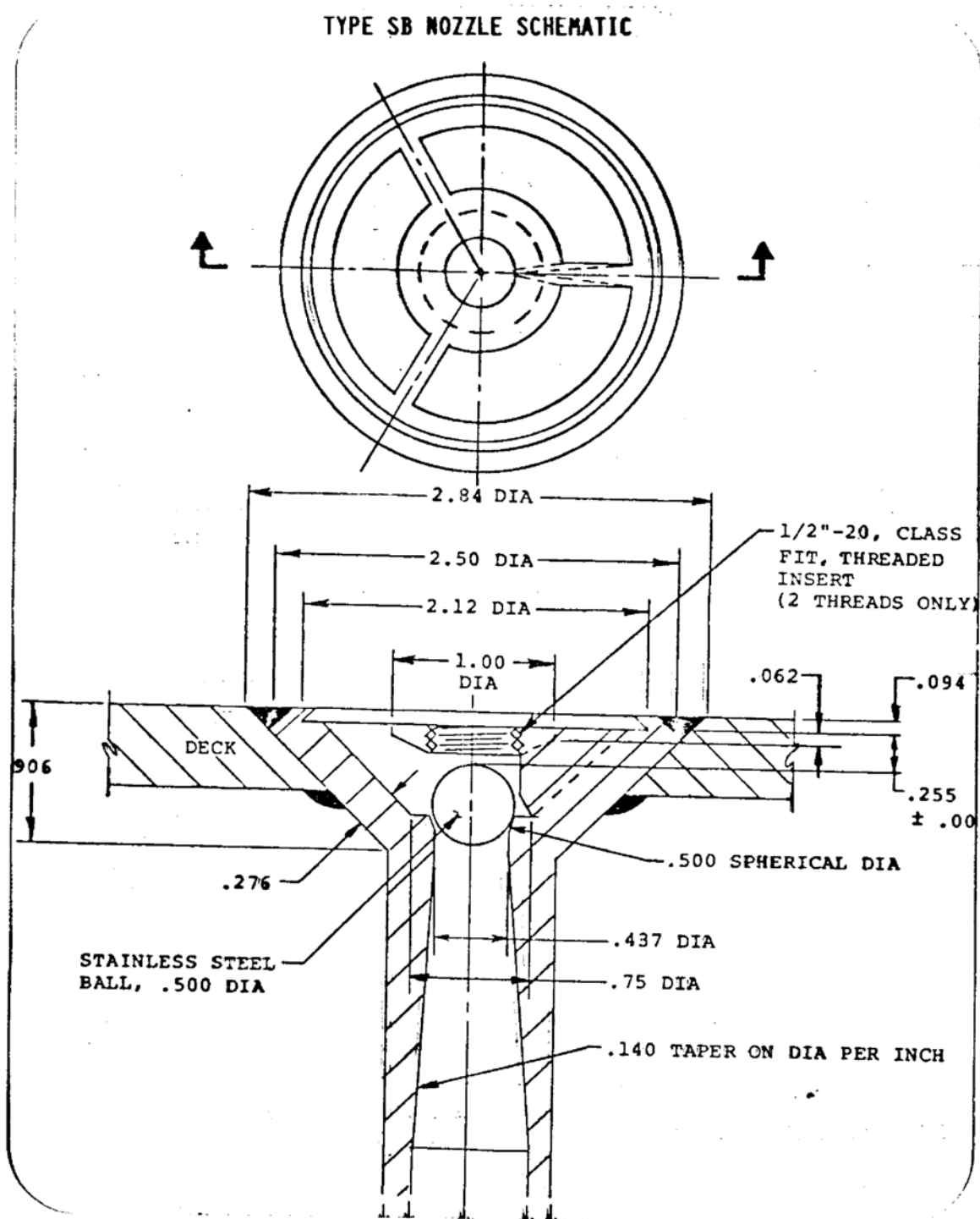
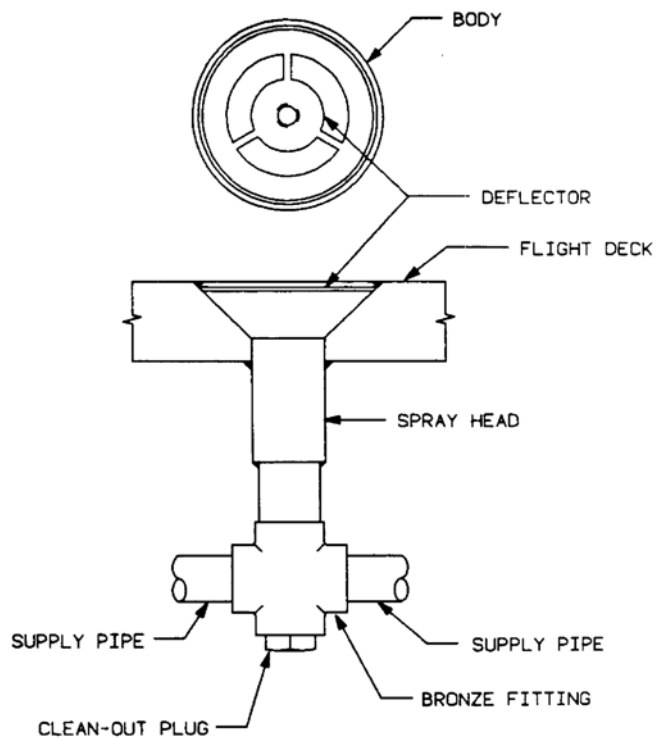


FIGURE 54. Flush-Deck Nozzle.



NOTE - NO CLEANOUT FITTINGS SHALL BE INSTALLED IN SPACES CONTAINING ELECTRONIC EQUIPMENT. IN SUCH CASES THE CLEANOUT FITTINGS SHALL BE PROVIDED IN AN ADJACENT SPACE OUTSIDE OF THE ELECTRONICS AREA IF PRACTICABLE.

FIGURE 55. Clean-Out Fitting.



FIGURE 56. Deck-Edge Nozzle.

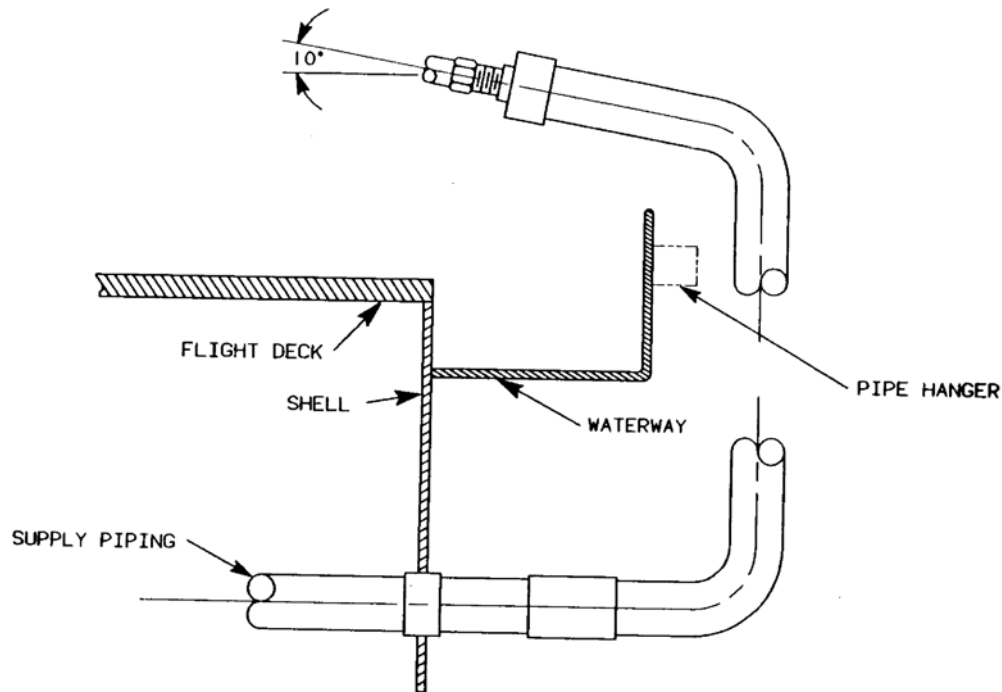


FIGURE 57. Schematic of Deck-Edge Nozzle.

In the plan view of the flight deck shown in Figure 58, each of the dots marks the location of a flight-deck nozzle. Hundreds of these are on the flight deck of a carrier. The dotted lines show how the flight deck is divided into different zones. Figure 59 shows a control panel as it might be laid out in Pri-Fly or the NAV Bridge. The skipper or the Air Boss will have a plan view of the flight deck. If he sees a fire, he can immediately push the button to discharge AFFF selectively to any or all zones. The same system can be used to direct water on the flight deck for chemical, biological, radiological (CBR) washdowns and pre-wetting purposes.

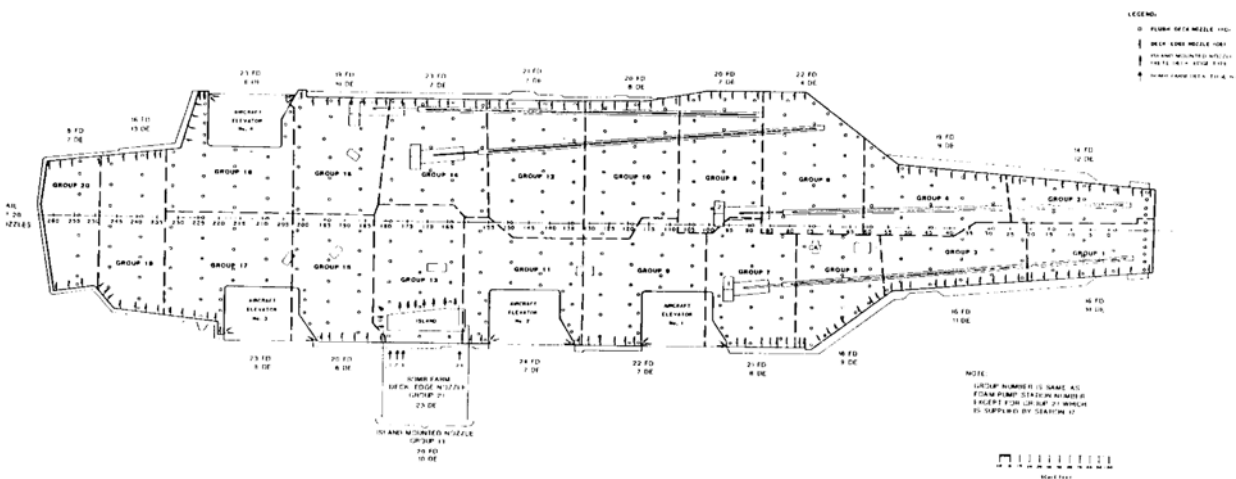


FIGURE 58. Flush-Deck Nozzles in Plan View.

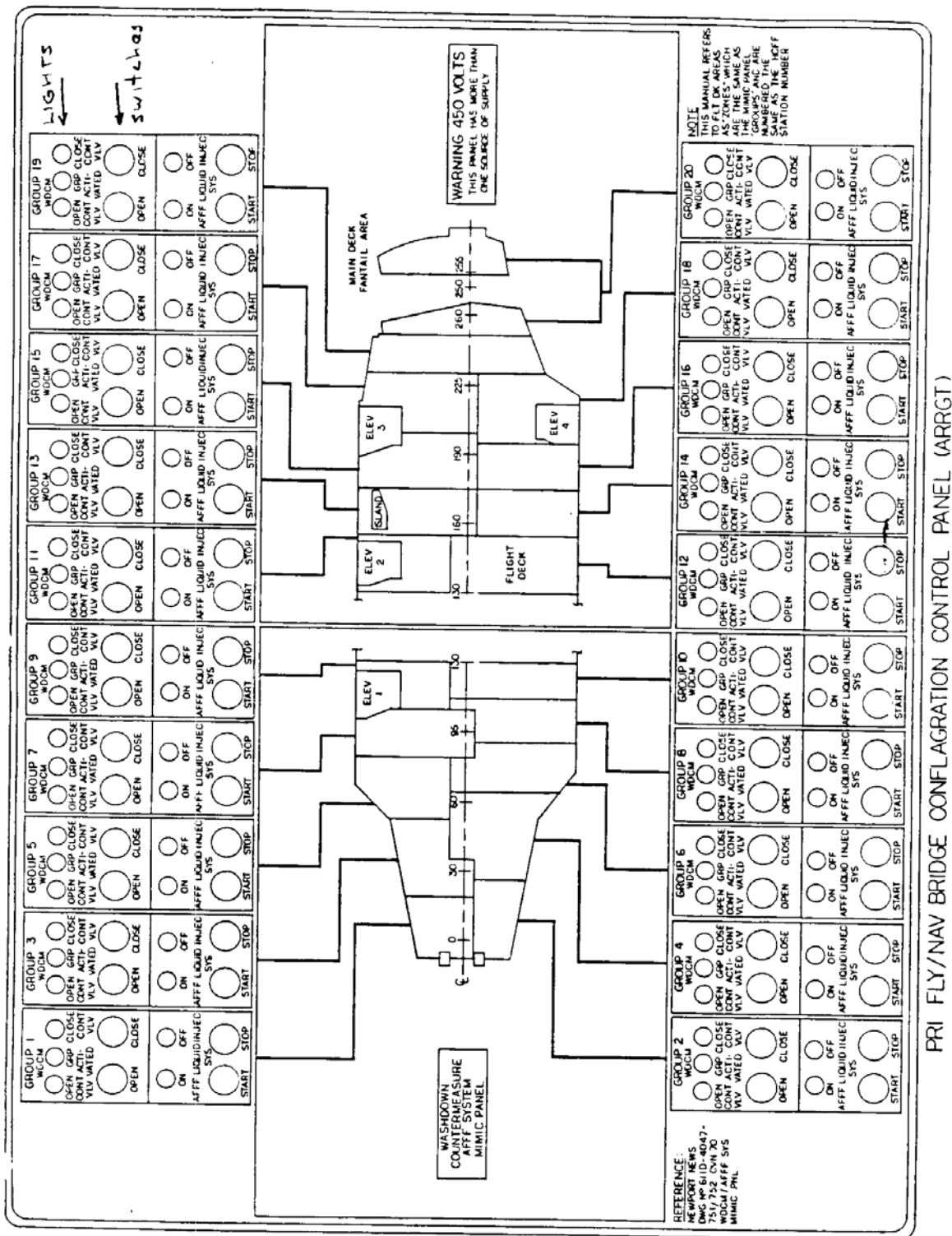


FIGURE 59. Control Panel.

Figure 60 shows the location of hose stations on the flight deck. Figure 61 shows a typical drill scenario with two hose teams in operation forward of the aircraft and on the side. Figure 62 is a photograph of the P-25 flight and hangar deck fire truck. This unit carries 750 gallons of water and 50 gallons of concentrate and has its own proportioner. It has a turret that can be operated by the driver (500 gpm). The vehicle has pump-and-roll capability so it can discharge the turret while rolling in on a fire. For serious events, the truck can be nursed from a hose at a catwalk, so that this truck can pump for as long as AFFF is supplied from a second-deck station. It provides a tremendous capability on the flight deck and the hangar deck. For small fires, internal to engines or fires in avionics compartments where a liquid agent could do damage, Halon 1211, considered a clean agent, is stored in four 20-lb extinguishers on the P-25.

Figure 63 is the previous version of the flight-deck fire truck called the P16. In this past year, these have been replaced by the new P25s. The P25s are kept on patrol constantly, depending on the nature of evolutions on the flight deck. In Figure 64 launch on No.1 and 2 catapults is in preparation, and the flight deck firefighting vehicle is positioned to protect during the launch. They would be strategically positioned, depending on fueling and de-fueling evolutions and helicopter operations. A minimum of two P25s are on every flight deck and constantly in motion, providing a great initial-response capability.

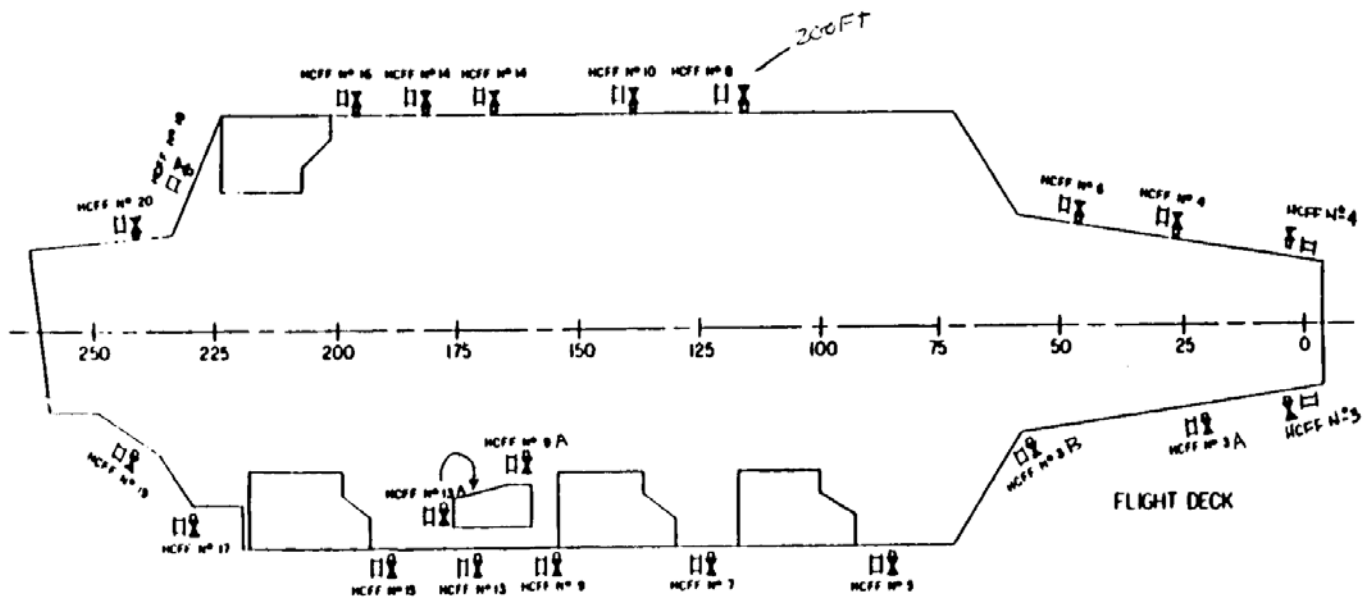


FIGURE 60. Flight Deck Hose Stations.



FIGURE 61. Hose Team Training Exercise.

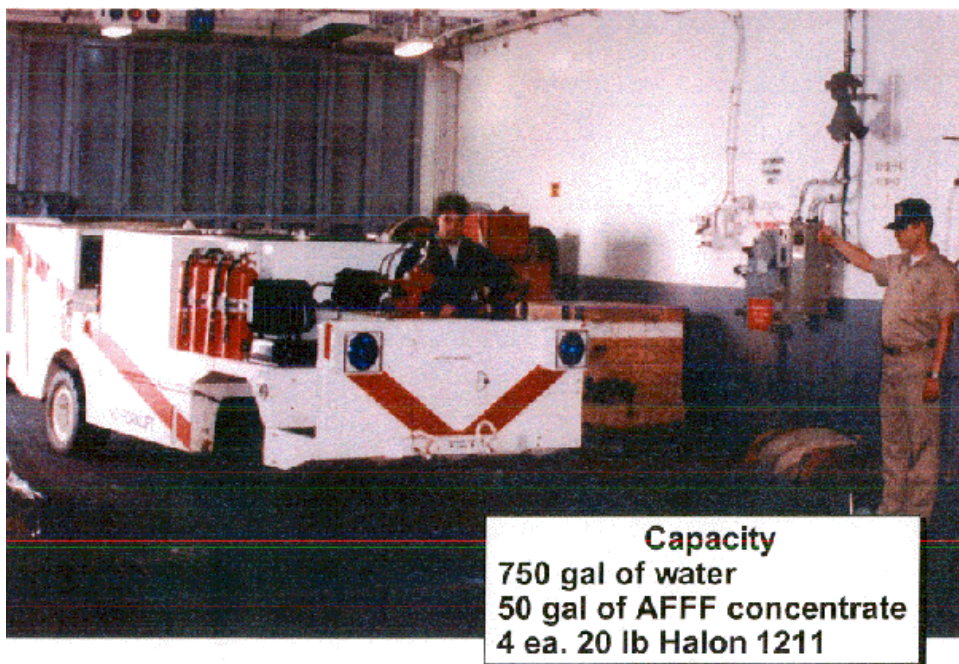


FIGURE 62. P-25 Firefighting Vehicle.



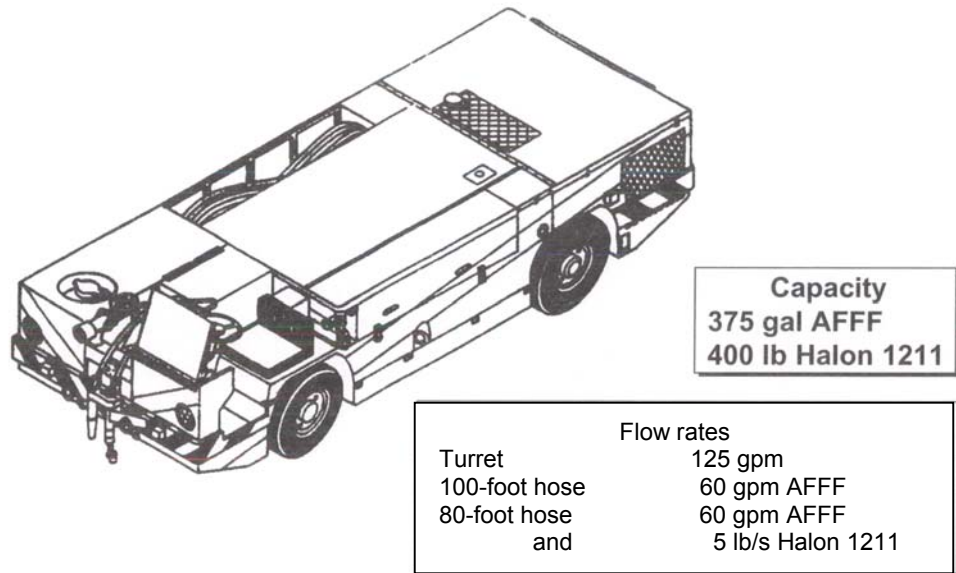


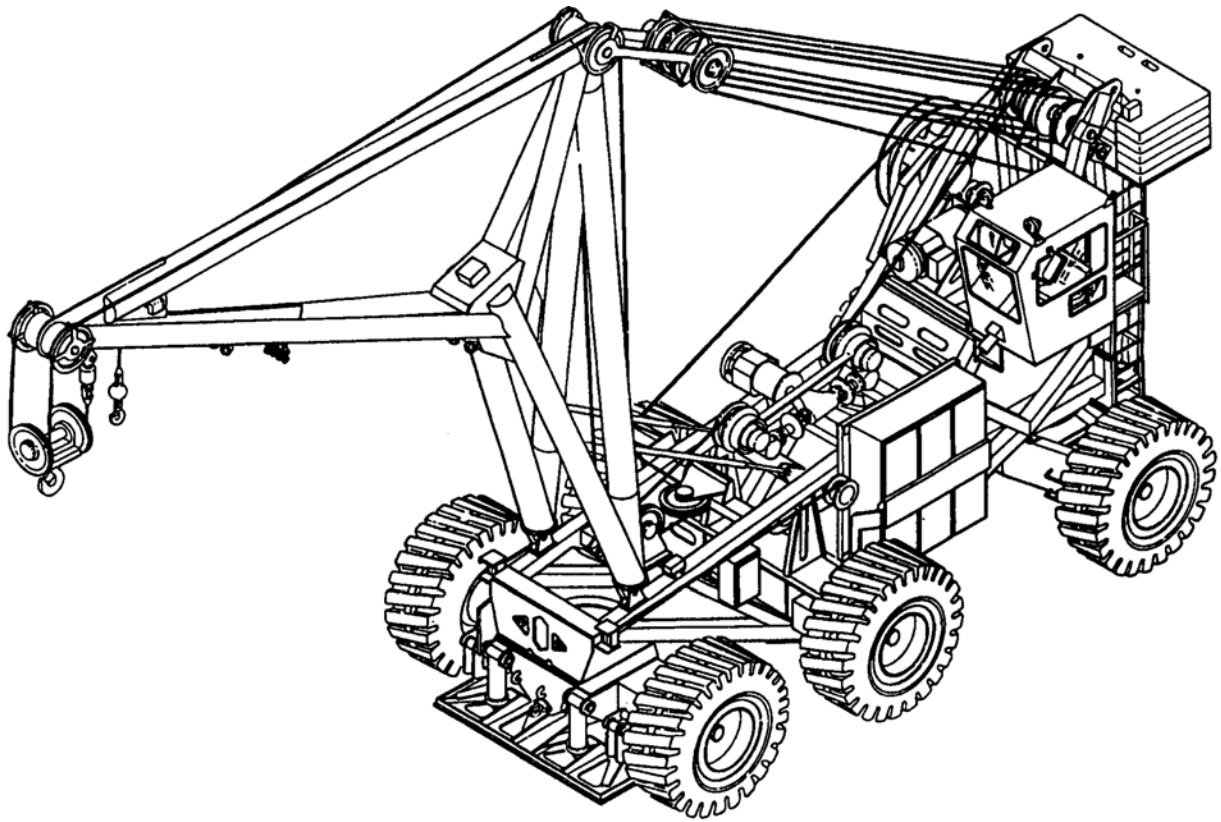
FIGURE 63. P-16 Firefighting Vehicle.



FIGURE 64. Vehicle Strategically Positioned.

Figure 65 shows some of the other yellow gear that can be used in a flight-deck crash. The "Tilley," the crash crane that can be used to lift or move disabled aircraft is shown in Figure 66. A crash dolly is shown in Figure 67. All carriers will have a crash forklift (Figure 68). Most of them configure a man basket on the forklift. If a fire occurs in a jet engine that is high above the deck, like a high engine on a helicopter, they can put a man in the basket, lift him up, hand him an extinguisher or hose-line, and he can put out the fire.





*AIRCRAFT SALVAGE CRANE, A/S32A-35*

The A/S32A-35 Aircraft Salvage Crane is a self-propelled, 4-wheel drive, diesel-electric-powered vehicle mounted on pneumatic rubber tires. The crane can lift crashed or damaged aircraft from various locations and attitudes and move the load on a rolling and pitching ship to a designated safe parking area on the flight deck. The crane is capable of operating in inclement weather and is designed for stowage on the flight deck.

Reference: NAVAIR 19-25G-19; NSN: 2VX-3810-01-360-3851; PN: 3075AS100-1

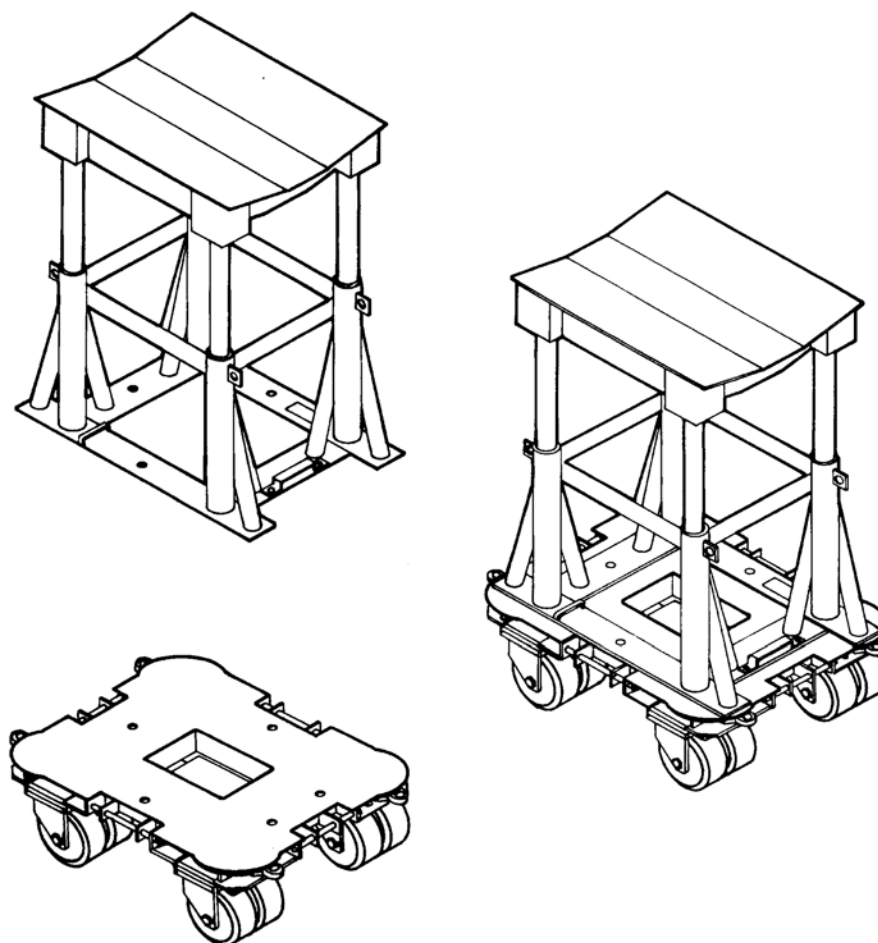
#### LEADING PARTICULARS

Characteristics	
Lifting capacity	<u>DYNAMIC</u> - 65,000 lb @ 25-ft outreach and 25-ft min. hook height <u>STATIC</u> - 75,000 lb @ 25-ft outreach and 25-ft min. hook height <u>ANCHORED</u> - 120,000 lb @ 25-ft outreach
Weight	132,500 lb
Hoist speed (rated load)	20 fpm
Height	32 ft (approximate with boom parallel to flight deck)
Width	15 ft 2 in.
Length (less boom)	34 ft
Overall length (boom parallel to flight deck)	59 ft

FIGURE 65. Aircraft Crash/Salvage Crane.



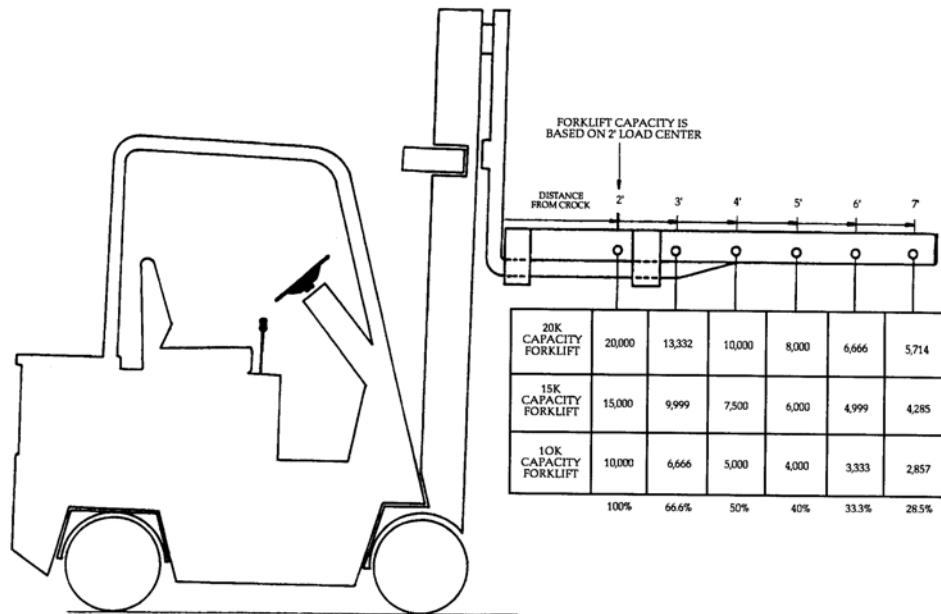
FIGURE 66. Aircraft Being Lifted.

*AIRCRAFT CRASH DOLLY AND ADAPTER AHU-24/E*

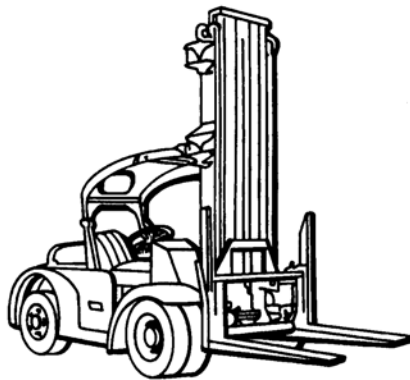
Four (4) Aircraft Crash Dollies and two (2) Adapters are provided on all aircraft carriers to move heavy aircraft components and to aid in moving crashed or immobile aircraft. Each dolly is capable of supporting a 32,000- pound load. The crash dolly may be configured many different ways in order to meet the demands of each salvage operation.

PN: DOLLY-1359AS201-1  
ADAPTERS:  
CONCAVE-1359AS251-1  
FLAT-1359AS302-1

FIGURE 67. Aircraft Crash Dolly.



CRASH FORKLIFT , NF-20



The Crash Forklift is used to partially lift aircraft in certain situations. It is highly maneuverable and most useful in those salvage operations that involve the damage or collapse of one (1) landing gear. It is diesel powered and equipped with pneumatic tires. Forklifts are rated to a maximum safe lifting capacity. The rated weight should never be exceeded. The crash forklift normally used for CV salvage operations has a maximum safe lifting capacity of 20,000 pounds at 24-inch load centers. Occasionally, a 15,000-pound capacity forklift may be used on CV or amphibious aviation ships. Lifting capacity decreases as the load moves outward from the heel of the forks. See the table above.

FIGURE 68. Crash Forklift.

Figure 69 shows the location of hose stations on the hangar deck. One Conflag Station is in each hangar bay. Figure 70 shows a typical AFFF hose station. On the right is the 1.5-inch flow-through AFFF reel, and to the left of that is 2.5-inch soft hose flaked on a rack. Right above that is a green box and a smaller green and red box, the controls that activate the AFFF system to supply the hose station. You can also turn on the AFFF overhead sprinkler from that same location. To the left a portable extinguisher is mounted at each hose reel.

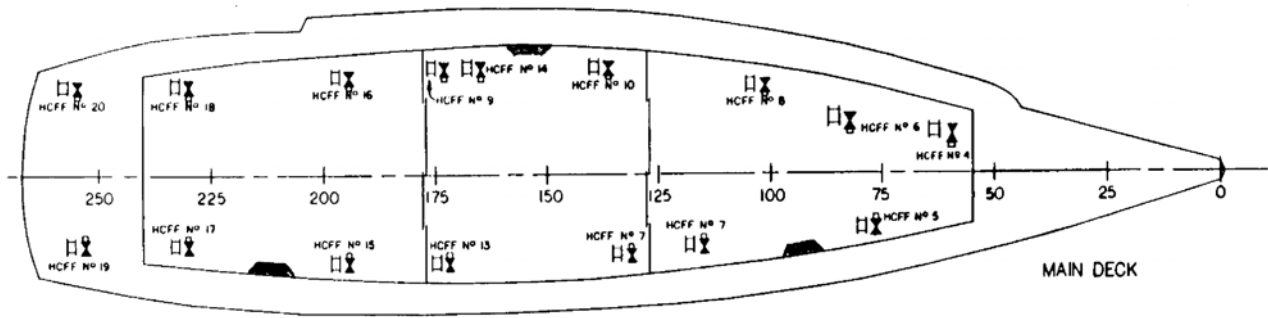


FIGURE 69. Hose Station Main Deck.

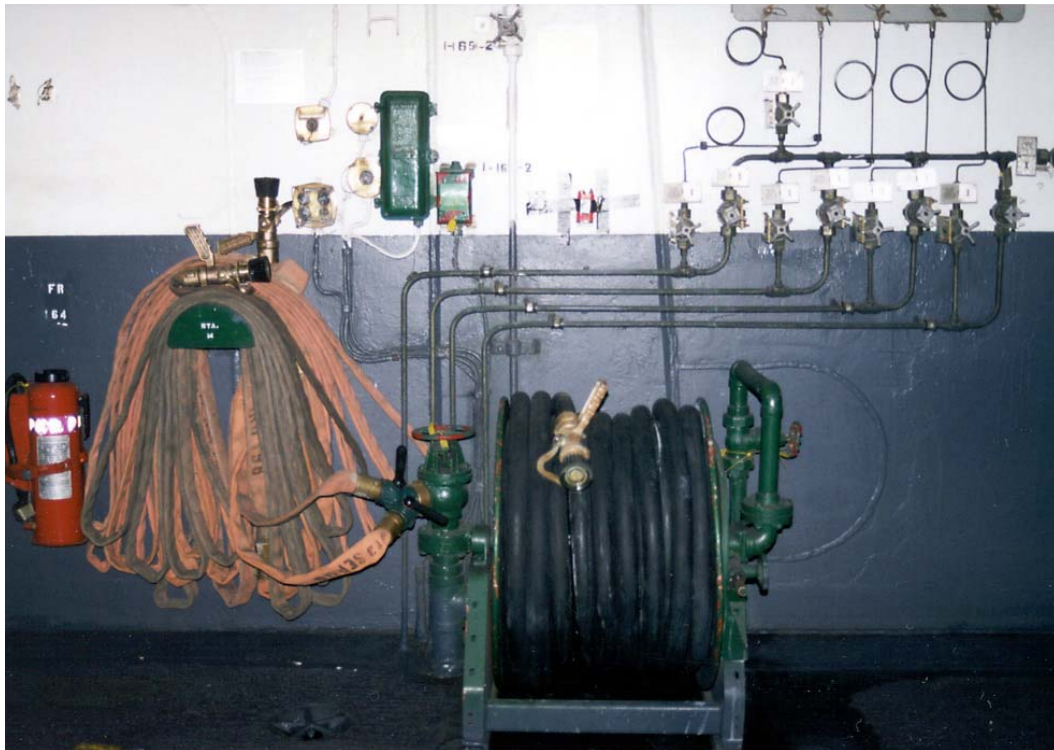


FIGURE 70. Typical AFFF Hose Station.

Figure 71 shows the control panel in Conflag Station No. 1. The Conflag operator has controls for each one of the hangar bay sprinkler groups and to turn on the AFFF in the lower-stage weapons elevators. Figure 72 is for a different Conflag station, again showing the controls that the Conflag operator has. Figure 73 shows the location of the high-capacity fog-foam stations, the proportioning stations, on the second deck. These extend throughout the second deck from the bow to the stern on both the port and starboard sides.

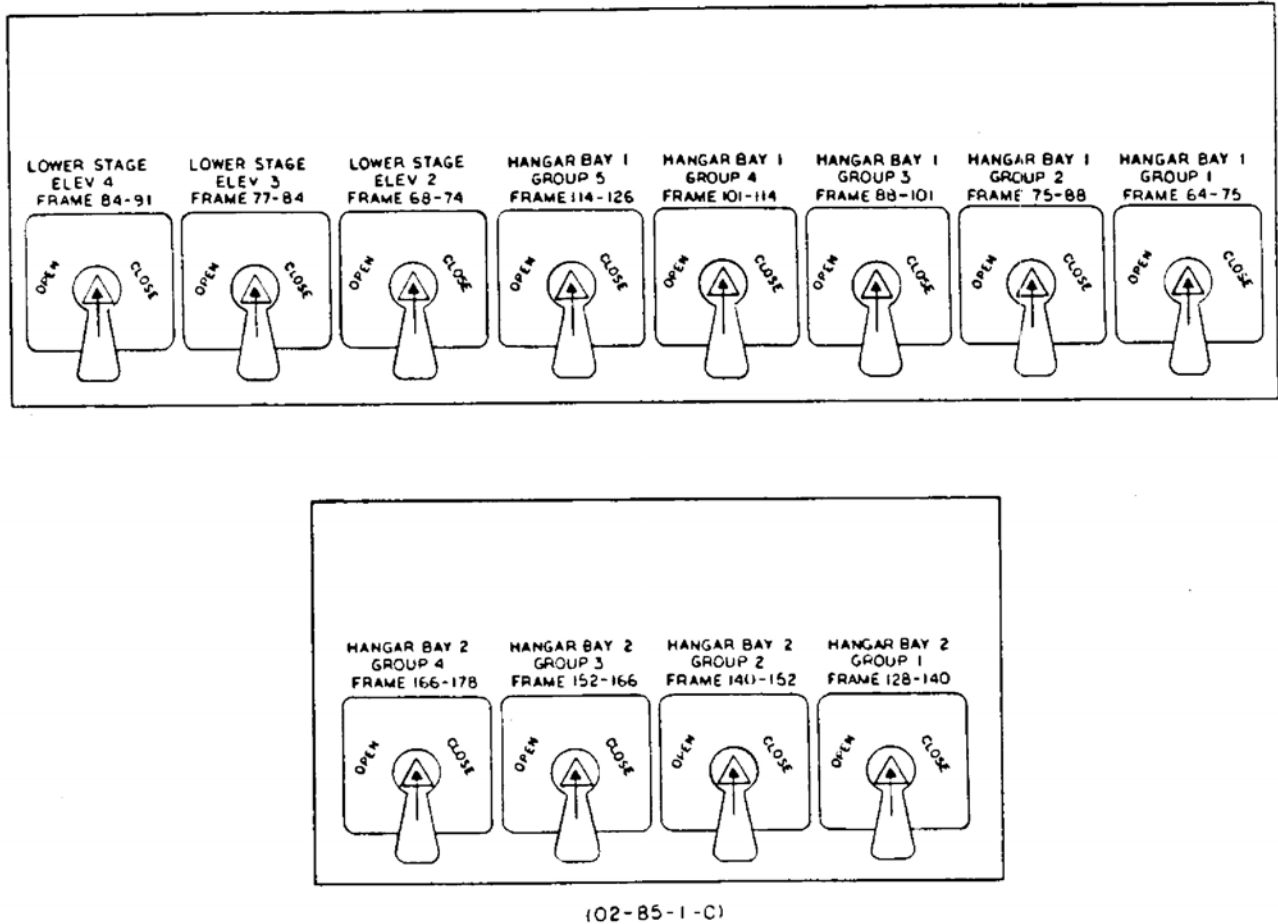
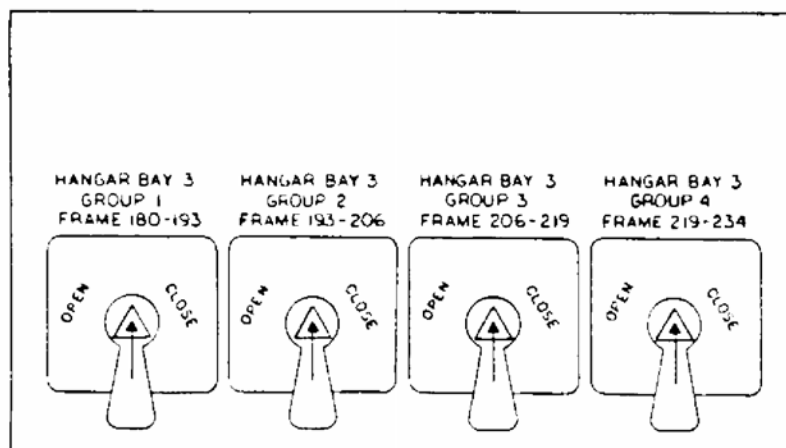
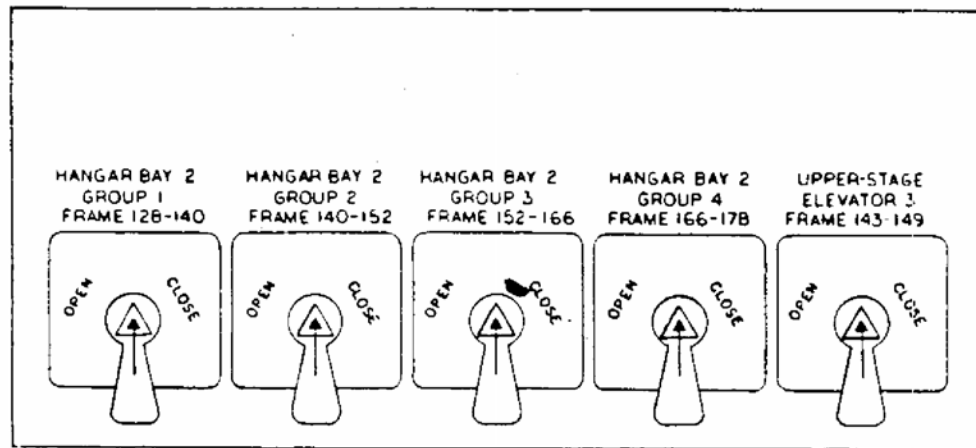
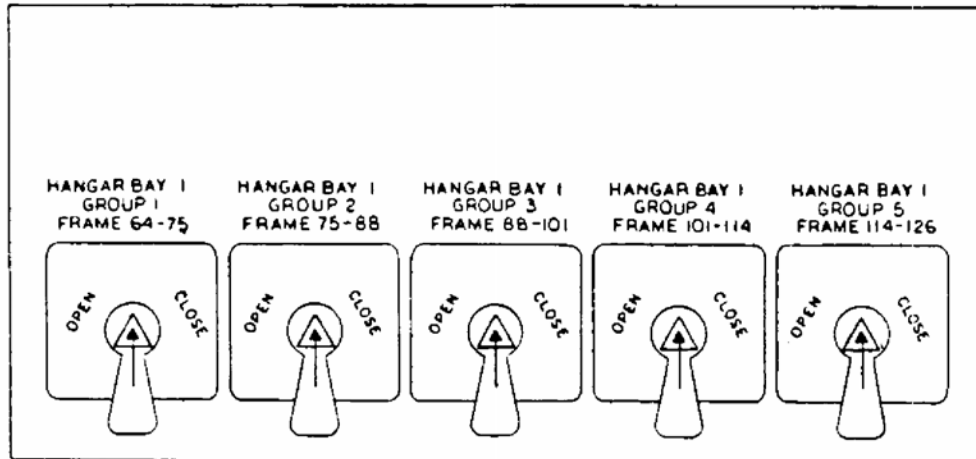


FIGURE 71. Control Panel Conflag Station No. 1.



(02-150-2-C)

FIGURE 72. Control Panel Conflag Station No. 2.



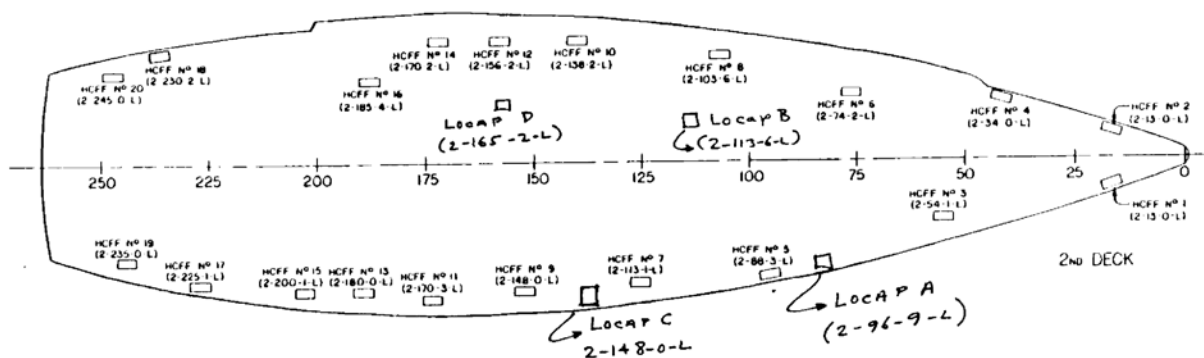
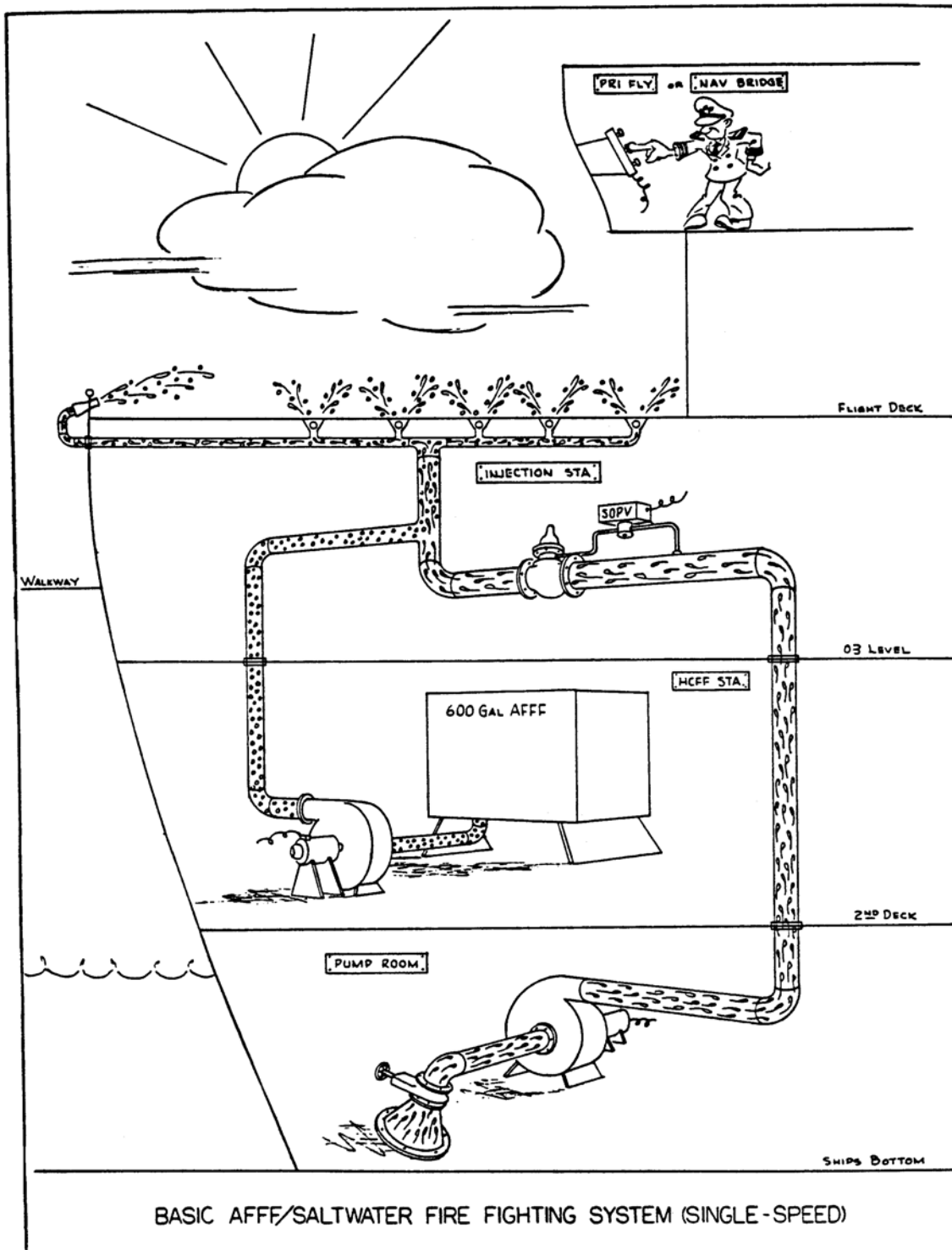


FIGURE 73. HCFF Station on the Second Deck.

Figure 74 is a cartoon illustrating how the proportioning station injects AFFF, pumps it up to the 03 level and into the seawater, and discharges a nominal 6% solution on the flight deck. Figure 75 similarly shows how the proportioning stations serve the hose outlets and sprinkler systems. Figure 76 shows the hard-pipe AFFF tank-to-tank transfer main on the second deck. Figure 77, which is rather complicated, shows the typical arrangement of the piping, valves, and controls for all the AFFF demand points.

The only possible criticism of this current system is that it is a vertical-feed arrangement, meaning that each demand point is fed below by one, and only one, high-capacity fog-foam station. So you do not have the ability to feed a hose station from another proportioning station if its dedicated proportioning station is out of commission. The only exception to that is sprinkling in the hangar bay.

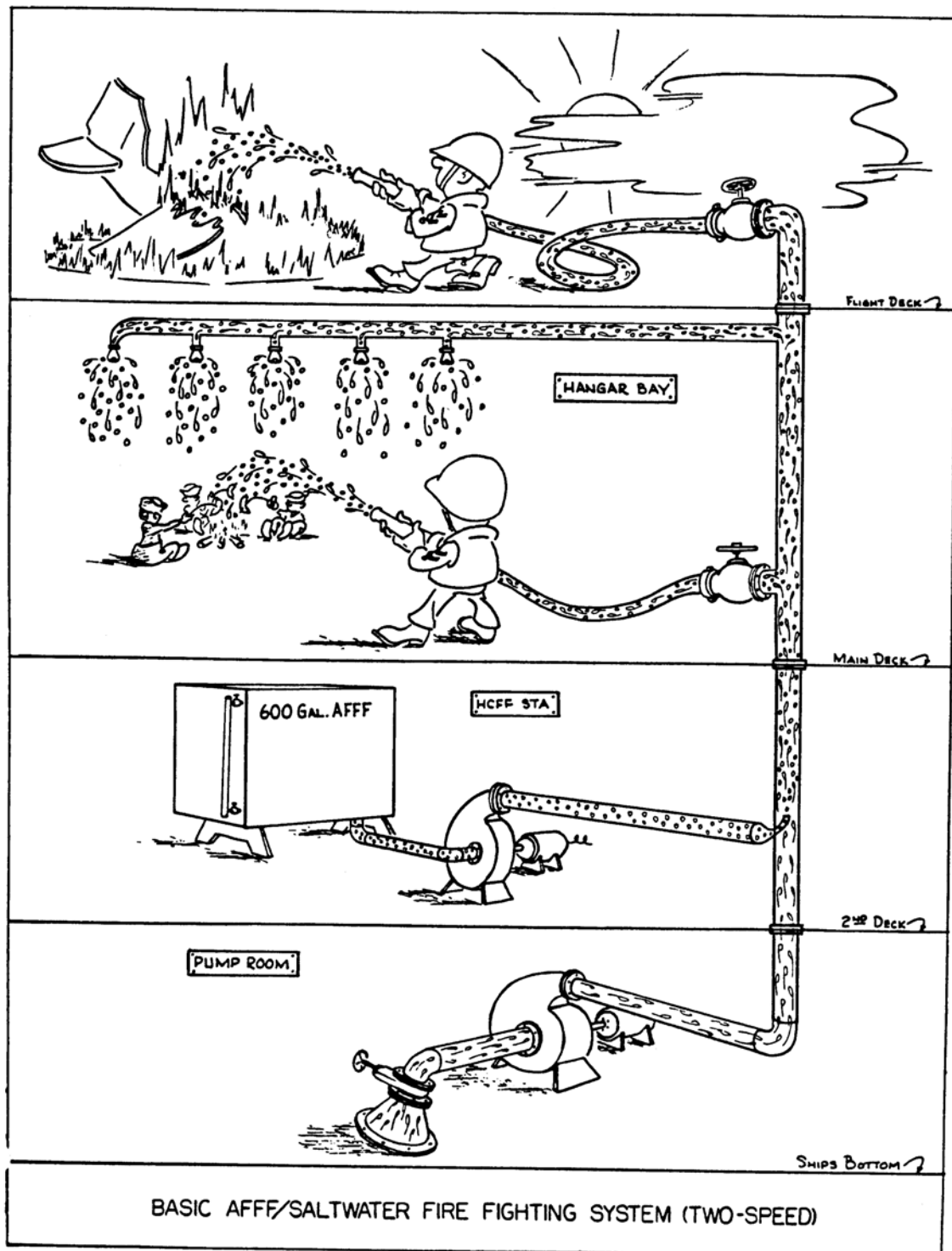
As shown in Figure 78, every hangar bay sprinkling group is fed from two separate stations; one on the port side and one on the starboard side. If you were postulating a hit in the hangar bay as part of a LFT&E analysis and considering that the hangar bay sprinkling group may be damaged from the detonation, one important consideration would be whether that damage occurs above or below the check valve installed in the riser in each supply line. A check valve is on each side so that if one proportioning station should be out of commission, you would not pump AFFF from the other side back into that station. If you had a break below that check valve, you would still be able to supply that group from the other side. The flow would be reduced, but you would still be able to distribute AFFF into that area of the hangar bay. If the break occurred above the check valve, the situation would be different because the supply from both sides would be going through the break. Very little would be going through the sprinkler systems, which could be a factor in doing LFT&E analysis on a hangar bay hit.



1-0.1

FIGURE 74. AFFF Injection System.

0905-LP-092-4000



1-0

FIGURE 75. AFFF Proportioning.

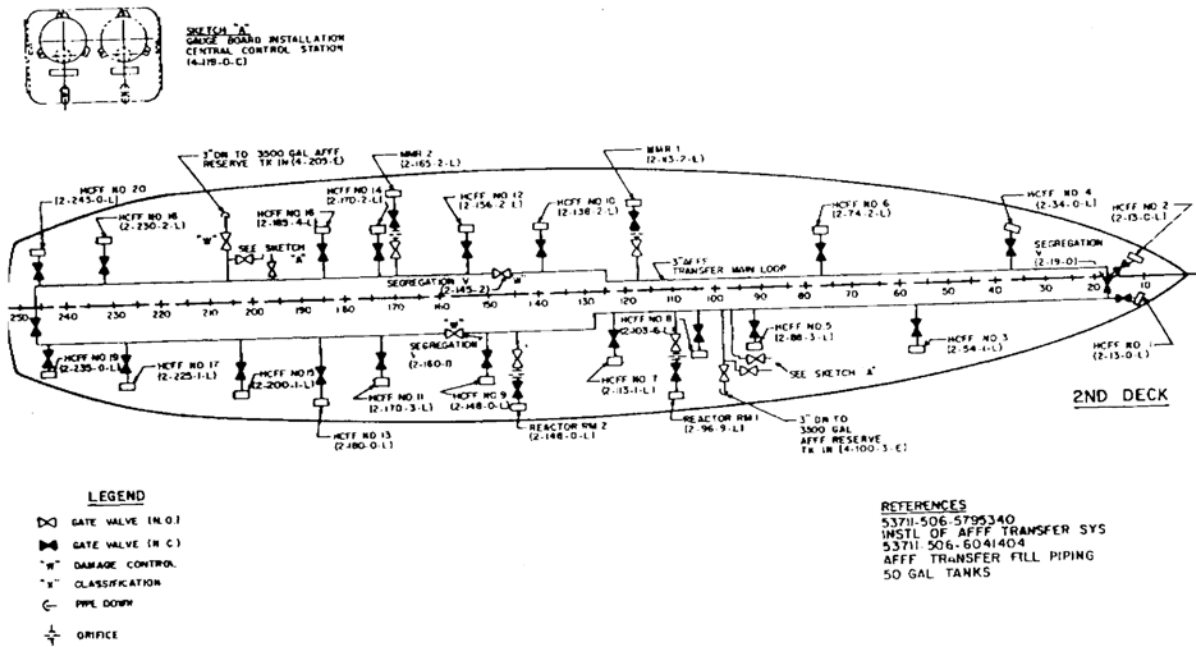


FIGURE 76. AFFF Concentrate Transfer Main.

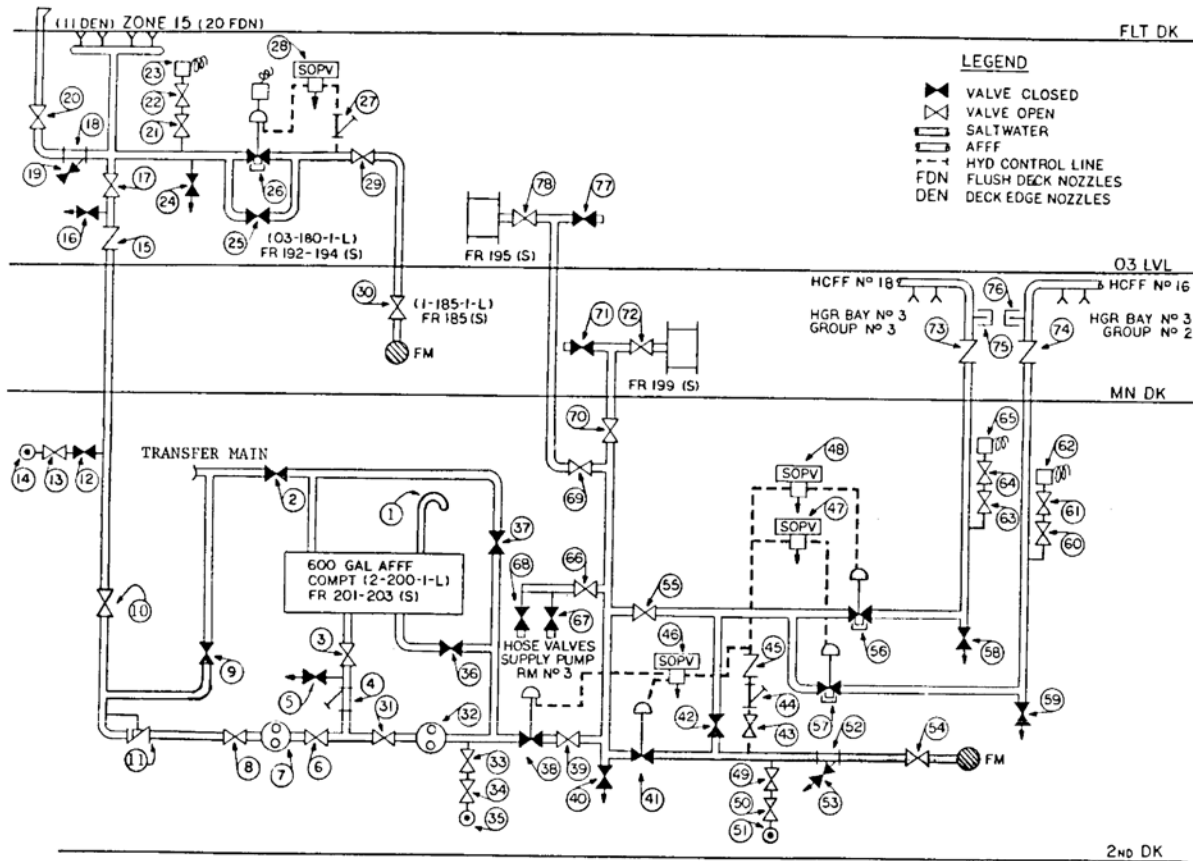


FIGURE 77. HCFF Station Schematic.

# "HANGAR BAY LOOP" 2-SPD SYSTEM

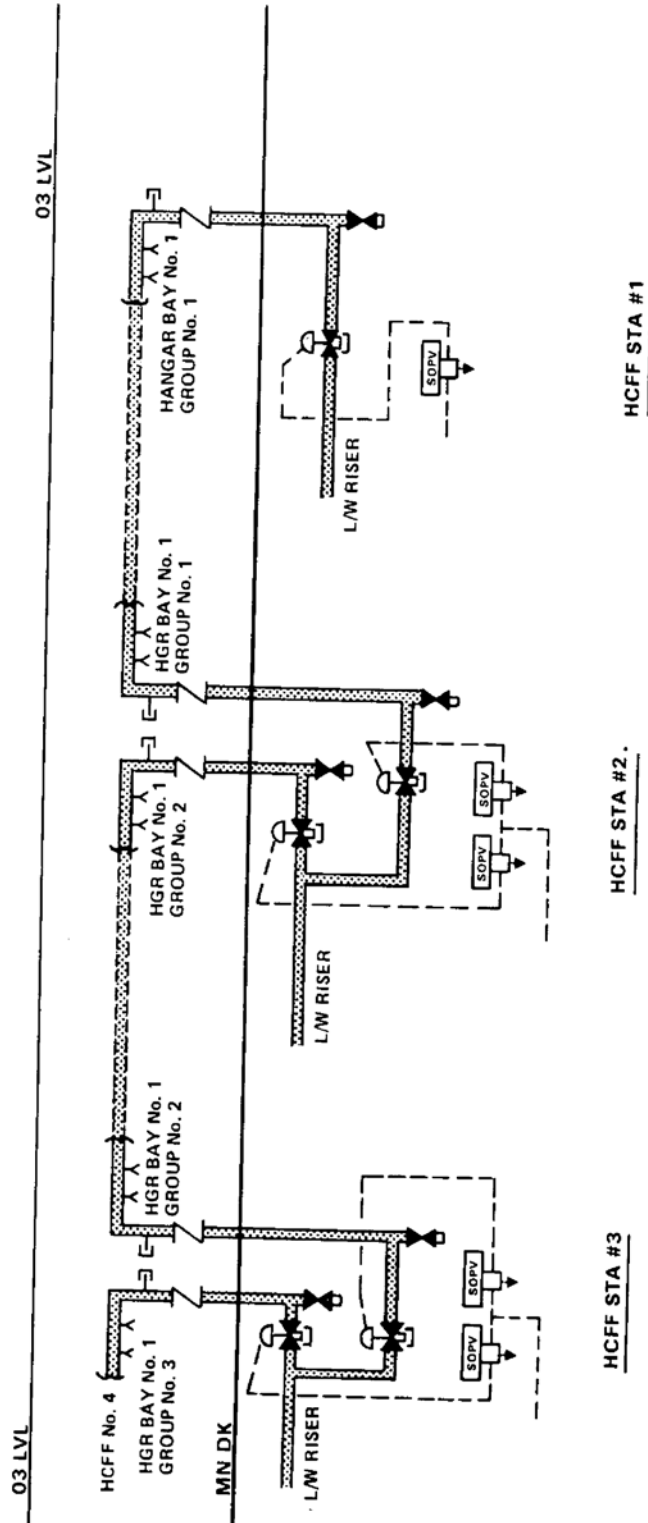


FIGURE 78. Hangar Sprinklers Dual Supply.

## FIREFIGHTING PROCEDURES AND TACTICS

The firefighting procedures used on the flight and hangar deck are spelled out in the Navy's NATOPS manual for aircraft firefighting and rescue, shown in Figure 79. NAVAIR PMA 251 is the designated model manager for this particular publication, which contains a specific chapter dedicated to aircraft carriers. The current tactics on the flight deck are contained in Figure 80. In an immediate first attack, anyone in the vicinity is expected to fight the fire using either a portable extinguisher or an AFFF hose reel (Figure 80a). Every person who has a job requirement on the flight deck is required to be trained in deployment of the hose reels and portable extinguishers. Next, the mobile firefighting vehicle in some cases could arrive before the man who grabs the first appliance. Following the response of the mobile firefighting vehicle would be the response of the organized hose teams.

The current NATOPS requires a minimum of four AFFF hoselines for every flight deck fire. The number of men, both minimum and maximum, is designated for each size hose. The maximum was put in after the fires on the *Forrestal* and *Enterprise* when we realized that so many men were on a hose that it looked like a centipede, hindering not only the coordination of the movement of the hoses but also putting more men in jeopardy. Five men could adequately handle a 1.5-inch hose and seven men a 2.5-inch hose. A minimum is also specified. A hose team leader is assigned for each hose line, the same as for below-deck fires. An on-scene leader is designated for the firefighting supervision. At the same time that the fire truck and hose teams respond, an announcement would be made over the Shipboard Intercom System "fire on the flight deck." All the second-deck HCFF stations would be manned then. If properly configured, they do not have to be manned to start delivering AFFF; delivery should be automatic at the push of a button. However, the HCFF stations are required to be manned during a fire on the flight deck, especially if re-supply from another station is needed. To pump AFFF concentrate from one station to another, manual reconfiguration of the valves below would be necessary.

Aircraft fueling operations would of course cease, and fuel pumps are required to be secured anytime fire on the flight deck is announced. The Hotsuitmen would be available for pilot rescue and would normally respond with the mobile firefighting vehicle. The ship is instructed to maneuver for favorable wind. Ideal wind speed would be 15 knots and the ship should maneuver to blow the fire over the side, not down the long axis of the ship. The background assistance team would muster and stand by and, if necessary, the mobile firefighting vehicle would be nursed by a hose from the gallery walkway. For any fire beyond the capabilities of the single hose team or for any multi-plane incident, the Air Boss is supposed to activate the installed AFFF wash-down system in both the fire zone and the upwind zone (Figure 80b). Actions would be taken to move uninvolved aircraft away from the scene, and the crash crane, forklift, and crash dollies would be deployed as necessary. Ordnance and lox carts would be rapidly moved away and jettisoned if necessary.

Hose-control devices are in essence hose couplings with an attached hook that have been provided to all the carriers. These allow the attachment of a nozzle to an aircraft carrier tie-down so AFFF can flow from a hose line, which can be abandoned if necessary in the event of actual or impending cookoff of ordnance. The bomb farm and weapons elevator AFFF systems are

activated as necessary. Separate fantail sprinkling can be activated for fires involving the fantail. Of course EOD people would be available to provide technical assistance. The current criteria initiated after the *Nimitz* incident require that after the fire is extinguished weapons cooling must continue for 15 minutes or until all weapons have been declared safe by EOD. After the fire is out, you would set the reflash watch, perform necessary salvage operations, clean up, and conduct a foreign-object-debris (FOD) walkdown to provide for a ready deck.

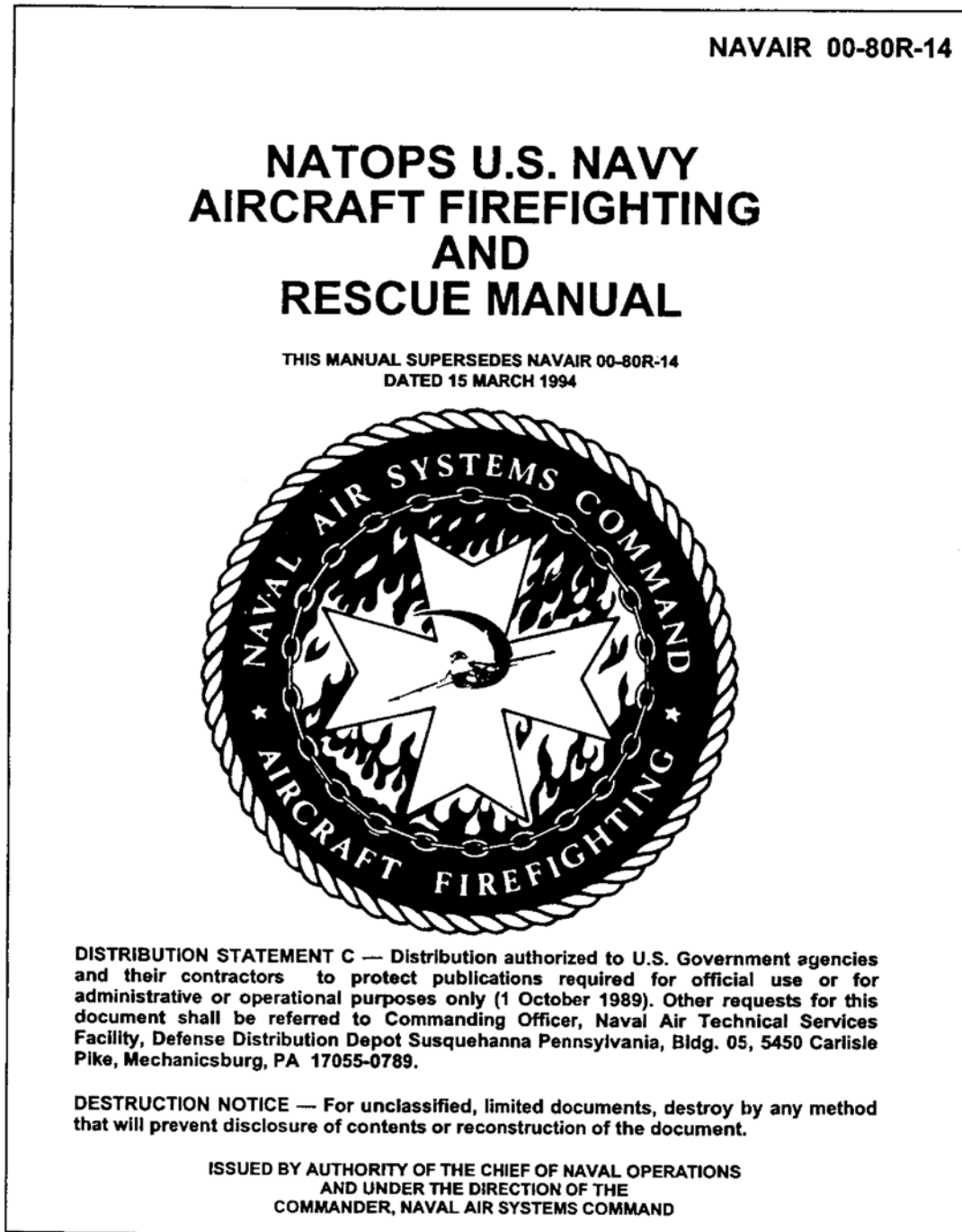


FIGURE 79. Cover of NATOPS Firefighting Manual.



**Current Tactics – Fire On the Flight Deck**

- Personnel in immediate vicinity deploy AFFF hose reel and/or portable extinguishers.
- MFFV responds
- Hose teams respond
  - Minimum of four AFFF hoselines
  - 3-5 men per 1 ½ inch hose
  - 5-7 men per 2 ½ inch hose
  - Hose team leader for each hoseline
  - Fire fighting supervised by on-scene leader
- Second Deck HCFF stations manned as “Fire on the Flight Deck” announced over 1MC
- Aircraft fueling operations cease and fuel pumps secured
- Hot Suitmen available for pilot/crew rescue
- Ship maneuvers for favorable wind
- Background assistance team and medical personnel stand by
- MFFV nursed

(a)

- Air Boss activates AFFF Washdown (fire area and upwind zone) if fire beyond capability of hose teams or if multi-plane incident
- Uninvolved aircraft moved away from scene (crash crane, fork lift, crash dollies as needed)
- Ordnance and LOX carts moved away (jettisoned if necessary)
- Hose control devices set up to protect ordnance
- Bomb farm and weapons elevator AFFF systems activated if necessary
- Fantail sprinkling activated if necessary
- EOD personnel provide technical assistance
- After fire extinguished, weapons cooling continues for 15 minutes or until weapons declared safe by EOD
- Reflash watch set
- Salvage operations, clean up and FOD walkdown performed to provide “ready deck”

(b)

FIGURE 80. Current Tactics for Flight Deck.

Tactics on the hangar deck (Figure 81) are very similar to the following additional procedures:

1. Elevators are to be returned to the flight deck.
2. Division doors are to be closed.
3. The elevator doors are supposed to be closed; though a NATOPS change is pending to leave the elevator doors partially open to facilitate smoke removal.
4. Hangar deck lights are to be left on.
5. All weapons elevator doors and hatches are to be closed.
6. All doors and hatches to the interior of the ship are to be closed. Breathing apparatus is to be donned as soon as possible.
7. Background assistance would be established in the adjacent bay.
8. Cooling teams are to be posted on the opposite side of all doors.

Similar to the criteria for fixed system activation on the flight deck, the hangar AFFF sprinkler system is supposed to be turned on for any multi-aircraft fire or whenever a fire is deemed to be beyond the control of initial hose teams.

<p><b><u>Current Tactics – Fire on the Hangar Deck</u></b></p> <p>Similar to flight deck tactics, with following additional procedures:</p> <ul style="list-style-type: none"> <li>- Return elevators to the flight deck</li> <li>- Close hangar bay division doors</li> <li>- Close elevator doors (NATOPS change pending to facilitate smoke removal)</li> <li>- Leave hangar deck lights on</li> <li>- Close all weapons elevator doors and hatches</li> <li>- Close all doors/hatches to interior of ship</li> <li>- Don breathing apparatus as soon as possible</li> <li>- Establish background assistance in adjacent bay</li> <li>- Post cooling teams on opposite sides of doors</li> <li>- Activate appropriate zones of Hangar AFFF Sprinkling System for any multi-aircraft fire or when fire beyond control of hose teams</li> </ul>
--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

FIGURE 81. Current Tactics for the Hangar Deck.

## HISTORY OF FIRES

To review the history of some of the fires on carriers, we have summarized significant fires since World War II (Table 3). In this and subsequent figures is the date of the occurrence, the ship involved, the type of fire, how many people were killed, and the major lessons learned. Again, the emphasis here is only on fires occurring on or above the hangar deck. We have excluded from this list the numerous fires that have involved ship machinery spaces, propulsion plants, diesel generator rooms, fuel pump rooms, and similar spaces. Because this review covers only fires on the hangar deck and above, these fires could potentially involve the aviation areas on an aircraft carrier. As far as fires on the flight or hangar deck that occurred in World War II, we had numerous incidences because we had a considerable number of ships hit by enemy torpedoes, bombs—or later in the war—Kamikaze aircraft.

Figure 82 attempts to show the major carrier losses resulting from fires during World War II. That would include the *Lexington*, at the battle of Coral Sea, hit by three bombs and two torpedoes, which had to be abandoned because of the explosion of gasoline vapors. In those days Navy aircraft were fueled by gasoline, which was much more volatile and much more dangerous than today's kerosene-based fuel.

In June of 1942 at the battle of Midway, the *Yorktown* was hit by three bombs, which caused a massive fire. The *Yorktown* was ultimately abandoned and was later sunk by a Japanese submarine. At the battle of Santa Cruz a few months later, the *Hornet* was sunk by a bomber attack, which caused widespread fires. In Leyte Gulf, both *Princeton* and *St. Lo* were hit. On *Princeton*, a single bomb penetrated the flight deck and her magazines eventually cooked off. *Princeton* had to be abandoned and was then sunk by U.S. ships to keep it from falling into the hands of the Japanese. *St. Lo* was sunk by Kamikaze attacks. *Saratoga*, at Iwo Jima in 1945, was also knocked out of commission because of large fires caused by four Kamikaze attacks. The famous attack in the Japan Sea in March of 1945, the *Franklin* was destroyed by two bombs and 800 men were killed. That was one of our biggest losses of life on a single ship in World War II. Then in Okinawa, Kamikazes actually hit 12 ships that were classified as carriers. None of the ships in Okinawa were sunk, but there were major fires. A lot of ships were classified as aircraft carriers in those days; some were just aircraft transport ships, others were flight decks erected on top of cruisers.

TABLE 3. Significant Aircraft Carrier Fires Hangar Deck and Above.

Date	Ship	Fire type	No. of dead	Lessons learned
1940s WW II	Numerous	Flight deck crashes Enemy action torpedoes, bombs and Kamikazes	Many	Torpedo side protection Need foam systems Hangar Conflag stations Need division doors
9/51	<i>Essex</i> (CV-9)	Flight deck crash into pack	7	Maneuver for favorable wind
8/52	<i>Boxer</i> (CV-21)	Hangar deck (20 mm fired, bomb cook-off)	9	Improve foam system
6/53	<i>Oriskany</i> (CV-34)	Bomb fell to deck and exploded	2	- - -
10/53	<i>Leyte</i> (CV-32)	Hydraulic catapult explosion	37	Hydraulic fluid hazard
5/54	<i>Bennington</i> (CVS-20)	Hydraulic catapult explosion	106	Hydraulic fluid hazard
1/58	<i>Kearsarge</i> (CVS-33)	Hydraulic catapult explosion	3	Hydraulic fluid hazard
1/58	<i>Essex</i> (CV-9)	Flight deck crash	?	
1/58	<i>Hancock</i> (CV-19)	Flight deck bomb explosion	?	
5/59	<i>Essex</i> (CV-9)	Flight deck crash	3	Foam system malfunction
8/59	<i>Wasp</i> (CVS-18)	Hangar bay fire (entire bay)	2	Need better foam coverage
12/60	<i>Constellation</i> (CV-64)	Hangar bay fire during construction	50	Restrict wood smoke, serious problem
10/66	<i>Oriskany</i> (CV-34)	Hangar bay flare fire	44	Flare safety need EEBDs
7/67	<i>Forrestal</i> (CV-59)	Flight deck Conflag (Zuni across deck)	134	Ordnance and firefighting improvements
4/68	<i>Kitty Hawk</i> (CV-63)	Hangar A/C tire stowage	0	Sprinkler tire stowage areas
1/69	<i>Enterprise</i> (CVN-65)	Flight deck Conflag cart cooked Zuni	28	Convert to AFFF Modify washdown system Need insensitive munitions
7/69	<i>Forrestal</i> (CV-59)	Hangar A/C tire stowage	0	Sprinkler tire stowage areas
1/74	<i>Forrestal</i> (CV-59)	03 Level arson	0	Combustible furnishings Cable fuel load Protect vital spaces
5/74	<i>Saratoga</i> (CV-60)	03 Level hot work/smoking	0	Same as above plus seal cable penetrations
7/74	<i>Enterprise</i> (CVN-65)	01 Level VAST cutting/welding	0	Protect vital spaces Install Halon Hot work safety

TABLE 3. (Contd.)

Date	Ship	Fire type	No. of dead	Lessons learned
11/75	<i>Kennedy</i> (CV-67)	Av storeroom, collision (01 - 03 Levels)	1	Packaging flammability Sprinkler storerooms Mach space inlet vents
5/81	<i>Nimitz</i> (CVN-68)	Flight deck crash	14	AFFF system reliability and certification Modify FF tactics for ordnance Need FF stand-off Add hoses on bow
12/89	<i>America</i> (CV-66)	Flag plot 08 Level Electric short/space heater	0	Abandoned cable fuel load Need FF protective clothing
8/91	<i>Independence</i> (CV-62)	Hangar deck AIMD LOX fire	0	LOX safety improvement
8/94	<i>George Washington</i> (CVN-73)	Hangar deck Sponson MoGas	0	MoGas safety

### Examples of Carrier Losses In WW II

Lexington (CV-2): Battle of Coral Sea (May 1942)

Hit by 3 Bombs, 2 Torpedoes

Explosion of Gasoline Vapors - Abandoned

Yorktown (CV-5): Battle of Midway (June 1942)

Hit by 3 Bombs – Massive Fire

Abandoned – later sunk by Japanese Sub

Hornet (CV-8): Battle of Santa Cruz (Oct 1942)

Sunk by Bomber Attack

Princeton (CVL-23): Battle of Leyte Gulf (Oct 1944)

Single Bomb Penetrated Flight deck

Magazines Cooked-Off

Abandoned – Sunk by US Ships

St Lo (CVE-63): Battle of Leyte Gulf (Oct 1944)

Sunk by Kamikazes

Saratoga (CV-3): Iwo Jima (Feb 1945)

Decommisioned by 4 Kamikazes – Large Fires

Franklin (CV-13): Japan Sea (March 1945)

2 Bombs – 800 Men Killed

12 Carriers Hit by Kamikazes: Okinawa (May 1945)

None Sunk, But Major Fires

FIGURE 82. Carrier Losses in World War II.

Returning to Table 3, the major lessons learned from World War II were that we needed torpedo side protection. As far as firefighting on flight and hangar decks, a need existed for foam

systems (most fires in those days were fought by water spray) and for Conflag Stations in the hangar bay to provide a protected location in which to activate the firefighting systems. Also that division door would be helpful in limiting the size of the maximum fire area on a hangar bay.

The first serious fire reported after World War II was in 1951 on the *Essex*, when an aircraft crashed into the pack during a flight-deck landing. According to the report, the major lesson learned was that maneuvering the ship for favorable winds was an important tactical decision. A year later, 20-mm machine gun rounds fired on the hangar deck of the *Boxer* caused a fuel spill that ultimately lead to cookoff of a bomb. The investigation report pointed out the need for improved foam systems.

In 1953 on *Oriskany* (Table 3), a bomb fell to the deck and exploded. This information was all we could find on that particular incident. In 1953, 1954, and 1958 three very serious incidents involved catapult hydraulic fluids. In those days aircraft were launched by catapults powered by hydraulic fluid, not steam. Hydraulic fluid under pressure, when sprayed, can lead to a mist explosion. That is what happened on the *Leyte*, *Bennington*, and *Kearsarge*. Unfortunately on the *Bennington*, 106 people were killed. Shortly after the incident on the *Kearsarge* the Navy made the decision to use steam-powered catapults exclusively and get rid of the hydraulic catapults. A report in the archives records few details of a flight deck crash on the *Essex* in 1958. Another flight deck fire on the *Hancock* the same month ultimately led to a bomb explosion. The following year (Table 3), a flight deck crash occurred on the *Essex*. They had actually started to install foam systems then, but it would have been just protein foam. A foam system malfunction was reported in that incident. Later in 1959, a massive fire apparently occurred on the hangar bay of the *Wasp*. The major recommendation was for better foam protection in hangar bays.

During the construction of the *Constellation* at Brooklyn Navy Yard in 1960, a major fire spread from the hangar bay up to the flight deck. The *Constellation* was the last aircraft carrier the Navy attempted to build at one of their own shipyards. The hangar bay was loaded with wooden construction sheds and wooden scaffolding. A fuel spill caused by a forklift ruptured a fuel tank. Fifty people were killed, and some of them were New York City firefighters. Smoke was the primary cause of death. After that, the Navy started a serious program to restrict wood on ships during construction and overhaul.

Another famous fire was the one aboard *Oriskany* in 1966. A flare locker was on the starboard side, a ready service locker. As flares were being returned to the flare locker, the pull pin on a flare apparently got caught on the hinge pin on the door and the flare was activated. A man holding the flare, in his panic, tossed it into the flare locker and closed the door. A total of 650 magnesium parachute flares were consumed. The fire spread into the hangar where six aircraft were destroyed. The fire spread from frame 15 to frame 102, burned out of control for 3.5 hours, and 44 people were killed. The main lesson learned was that flare safety had to be improved. Those particular flares have now been banned from service (the old Mark 24s). Two separate pulls are required to activate the current flares. Not only does the ring pin have to be pulled, a separate pull must be by the lanyard when it is deployed underneath a parachute as a signal flare. The *Oriskany* was also the incident that caused the Navy to start developing an emergency escape-breathing device because most of the people killed died of smoke inhalation.

The fire on the *Forrestal* in 1967 occurred when a Zuni rocket shot across the flight deck, causing massive fires and explosions. A total of 134 people were killed. The major lesson learned was that we needed improvements to ordnance to reduce their susceptibility to cookoff. Major firefighting improvements were needed on the flight deck. The *Kitty Hawk*, in 1968, burned out the tire stowage area just off the hangar. The major lesson learned was to install sprinkler coverage where tires are stored, on all carriers. Tire-storage areas are now protected by overhead sprinklers. An incident similar to the flight deck fire on the *Forrestal* occurred on the *Enterprise* in 1969. Fewer people were killed because people were not in the bunks on the 03 level; a total of 28 people were killed. The major lessons learned were to convert to AFFF as soon as possible, to devise a way to modify the washdown system to discharge AFFF, and to put more emphasis on development of insensitive munitions.

These next figures illustrate the result of the fire on the flight deck of the *Forrestal*; some of these pictures were in a *Life Magazine* feature article. The large hole shown in Figure 83 is what happens when a Mk 82 bomb blows up on the flight deck. Figure 84 shows some of the damage to the ship the following day, and Figures 85 and 86 show the damage to aircraft; 21 aircraft were totally destroyed. There were seven bomb explosions, with fragmentation as low in the ship as the hangar bay. The largest bomb hole on the flight deck was about 20 by 16 feet in 1.5 inches of steel.

Altogether, 134 men were killed, 300 were injured, and 50 of those killed were in their bunks on the 03 level. During the incident 15 men were either blown, fell, or jumped overboard. The fire was initiated when a Zuni, for unknown reasons, shot across the deck from starboard to port, rupturing fuel tanks on an aircraft on the port side. The fuel instantly ignited, causing adjacent fuel tanks and ordnance to rupture. From there it escalated as more fuel tanks ruptured, more fuel was dumped on the deck, and more ordnance cooked off. The *Forrestal* is also famous for another reason: the pilot of the aircraft that was struck by the first firing of the Zuni was Senator John McCain. His book he gives an account of that incident.



FIGURE 83. Bomb Hole on *Forrestal*.





FIGURE 84. Aft End of *Forrestal*.



FIGURE 85. Destroyed Aircraft on the *Forrestal*.



FIGURE 86. Close-Up *Forrestal* Damage.

Figures 87 through 89 are from the fire 18 months later on the *Enterprise*. This fire occurred when a Zuni rocket pod was cooked off accidentally by the hot exhaust from a jet engine starting unit. The jet engine starting unit was parked so the exhaust impinged directly on a Zuni pod. They had shortened the starting hose; as the hose became frayed they cut off the worn ends and recoupled it. They reduced the length of the starting hose, which caused the starting cart to have to be moved closer to the aircraft. In this incident, it was actually so close that the hot exhaust cooked off the Zuni rockets. A total of 40,000 gallons of jet fuel were consumed. Figures 87 and 88 show the fire as it was covering the entire aft end of the flight deck. A total of 28 people were killed on the *Enterprise*, 343 injuries occurred, and eight holes were created in the flight deck as a result of the cookoff of bombs.



FIGURE 87. *Enterprise* Fire.



FIGURE 88. Fire Covers Aft End.





FIGURE 89. *Enterprise* Attacks Teams.

As indicated in Table 3, in 1969 a fire on the *Forrestal* involved tire stowage again. Again the recommendation was to provide sprinklers for tire-stowage areas. The *Forrestal* had another incident in January of 1974, caused by an arsonist who ignited drapes in the flag quarters, causing a serious fire on the 03 level fueled by cabling and by furnishings in the flag quarters. That incident led NAVSEA to initiate a program to reduce the combustibility of habitability items and furnishings and also to provide protection for vital spaces.

Similarly, there was an 03 level fire just 4 months later while the *Saratoga* was in port in Norfolk. The fire was caused by hot work. The lessons learned were similar to the 03-level fire on the *Forrestal* and led to a recommendation to seal cable penetrations. The cables running throughout the 03 level acted just like a fuse. The fire spread down the cable and into vital spaces. That fire resulted in a requirement to use multi-cable transits or stuffing tubes anywhere that cables penetrate vital boundaries.

Two months later, a fire on the 01 level of the *Enterprise* in the Vital Avionics Shop Test (VAST) area did a lot of damage because it burned up vital electronics equipment. Four months later, the *Kennedy* collided with the *Belknap* in the Mediterranean, which resulted in a fire caused by flames from the *Belknap* impinging on the side of the hull. The hull got hot, igniting flammable packaging inside a storeroom. The main lesson there was to try to reduce the amount of bubble wrap and flammable packaging for electronic equipment, to install sprinklers in storerooms, and also to modify the arrangement of air inlets serving machinery spaces. Smoke was actually ingested into the machinery space inlets, which had to be abandoned. All carriers have a selector switch in the machinery space to draw in machinery space ventilation air from

either the port or the starboard. By selection of the proper side, smoky conditions on the flight deck and the need to bail out of a machinery-space fire can be avoided.

In May of 1981, a crash into a pack of F-14s occurred on the *Nimitz*, and 14 people were killed. The *Nimitz* crash led to major improvements in the reliability of AFFF systems serving the flight deck. Firefighting tactics were modified to require cool ordnance for fifteen minutes. Additionally, guidance was sent out as a reminder to firefighting parties to realize that ordnance can cook off even after the fire is declared out.

Figures 90 and 91 are photographs of the flight deck and the hangar deck of the *Kennedy*. Scorch marks on the side of the *Kennedy* are evident in Figure 91. When the *Belknap* hit the *Kennedy*, the *Kennedy* was in the process of fueling aircraft, so all of the JP-5 fueling risers were pressurized. The fuel risers were ruptured by the *Belknap* and about 2,000 gallons of flaming jet fuel spewed down on top of the cruiser. While the *Belknap* was hung up underneath the angle deck, and until they were able to back off, the flames impinging on the side of the hull caused fires internal to the *Kennedy*.



FIGURE 90. *Kennedy* Angle Deck.



FIGURE 91. Scorch Marks on the *Kennedy*.

Figure 92 shows the fire area on the *Nimitz*. The crash, and resulting fire, occurred after an incoming EA-6B aircraft inadvertently lined up on the foul line rather than the centerline of the angle deck in night landing. The centerline strobe lights were out. The aircraft plowed into a pack of F-14s on the bow. Figures 93 through 95 show the fire on the bow. Initially the fire party had difficulties fighting this fire because they had to approach into the wind. No hose stations were all the way forward on the bow of the *Nimitz*, so they could not deploy hose lines forward of the incident. Because of this, all *Nimitz*-class carriers now have hose stations all the way forward, to allow better hose coverage for this sort of fire. Figures 96 through 98 were taken the day after and show the damage to some of the involved aircraft.

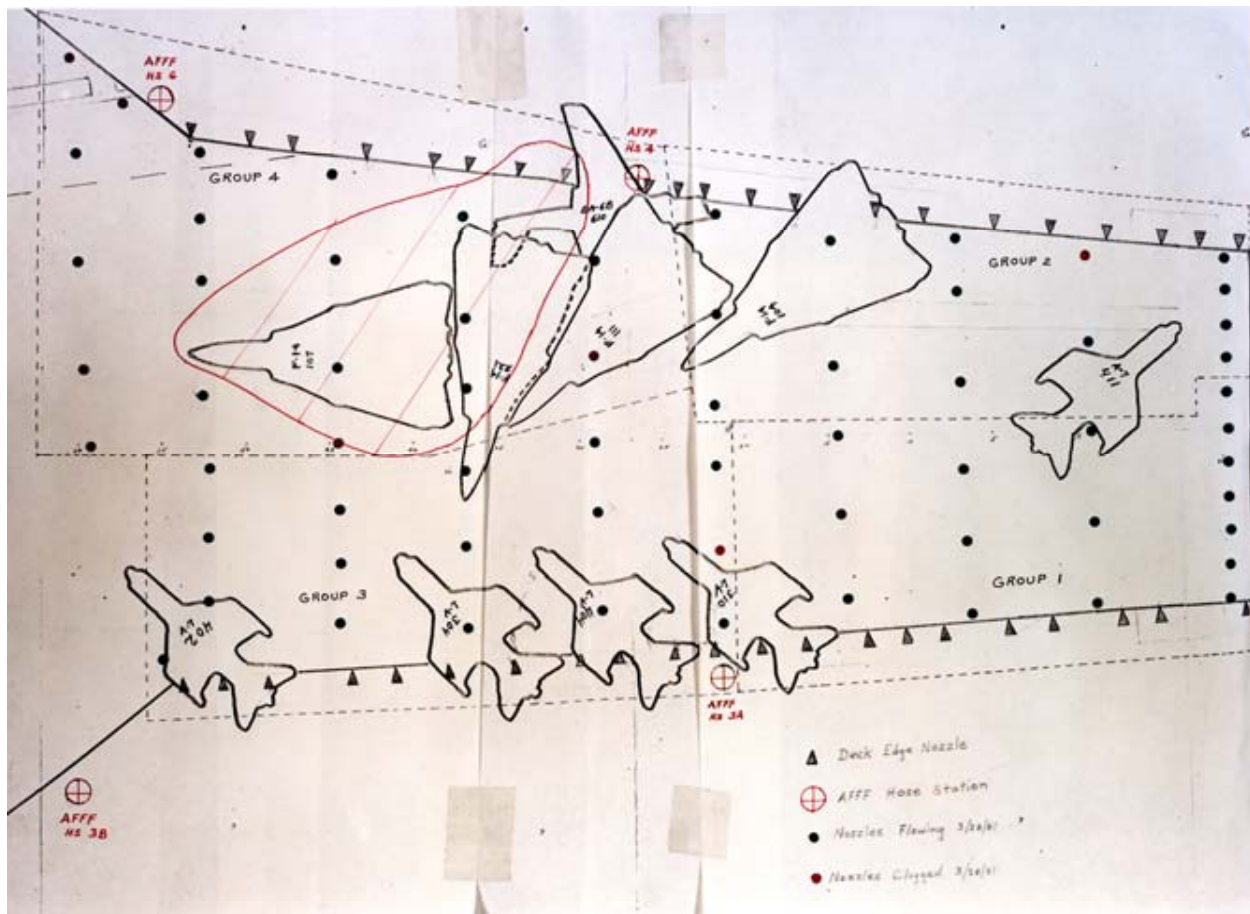


FIGURE 92. Fire Area on the *Nimitz*.



FIGURE 93. *Nimitz*—Fire on Bow.



FIGURE 94. *Nimitz*—Hose Teams Move In.





FIGURE 95. Intense Fire—*Nimitz*.



FIGURE 96. *Nimitz*—Post Fire Damage.



FIGURE 97. Close-Up of EA-6B Remains, F-14 in Background.



FIGURE 98. Totally Destroyed F-14.

Figure 99 summarizes the explosive reactions that occurred on the *Nimitz*. Cookoff of both a Sidewinder and a Sparrow, one after the fire was declared out, occurred. Members of the fire party stood around the debris, thinking that they were safe because flames were no longer visible. A delayed cookoff killed several people nearby. Also, 20-mm target-practice ammunition, six rocket-powered ejection seats, launcher cartridges, and canopy jettison devices

cooked off. Fortunately the Phoenix did not cook off, because the Phoenix might have had enough explosive energy to actually blow a hole in the flight deck. As it was, the explosions of the Sidewinder warhead and the Sparrow warhead shown in Figure 100 were not powerful enough to penetrate the flight deck. Figure 101 shows a dimple that was created in the flight deck, but the warhead piece did not penetrate all the way through the deck.

<u>EXPLOSIVE REACTIONS</u>	
<u>COOK OFF</u>	
AIM-9L (SIDEWINDER) GUIDED MISSILE	
WARHEAD LOW ORDER	
MOTOR FELL TO DECK AND BURNED	
AIM-7F (SPARROW) GUIDED MISSILE	
WARHEAD HIGH ORDER	
MOTOR LOW ORDER	
20 MM TP AMMUNITION	
EJECTION SEATS	
4 EA-6B	
2 F-14	
LAUNCHER CARTRIDGES	
EXPLOSIVE CANOPY JETTISON DEVICES	
<u>NO COOK OFF</u>	
AIM-54 (PHOENIX) GUIDED MISSILE	
RADOME DISINTEGRATED	
INTERNALS BURNED	
CHARRING	
AIM-54 (PHOENIX) GUIDED MISSILE	
MILD CHARRING	
AIM-7F (SPARROW) GUIDED MISSILE	
SEVERE CHARRING	

FIGURE 99. Ordnance Reactions on the *Nimitz*.



FIGURE 100. Remains of Missile Motor.



FIGURE 101. Dimple in *Nimitz* Flight Deck.

In December 1989, a fire occurred in the island structure of the *America* (Table 3). The fire, which originated in the Flag Plot on the 08 level, was thought to have been caused by an electrical short in a space heater. The fire ended up being significant because of the fuel load in the island structure. In 1991, a fire on the hangar deck of the *Independence* involved the liquid-oxygen area, which led to major improvements in liquid-oxygen handling and storage.

The most recent fire of any significance on a carrier occurred in August 1994 aboard the *George Washington*. This was on the starboard sponson off of the hangar deck and involved the burning of motor gasoline that was stowed temporarily to support outboard-motor-powered inflatable boats used by special operations teams. The flames actually rolled up to the flight deck, and aircraft had to be moved. The door between the sponson and the hangar deck kept the fire from spreading into the hangar deck proper. The major lesson learned in the *George Washington* fire was the need for stricter procedures for handling and stowing motor gasoline. Figures 102 through 105 show the results of the fire in the Flag Plot area on the *USS America*. As you can see, the main fuel load there was the PVC jacketing on cable insulation.



FIGURE 102. *America* Flag Plot Fire Damage.





FIGURE 103. *America* Flag Plot Damage.



FIGURE 104. Extensive Burning of Cables.



FIGURE 105. Close-Up of Cable Damage.

## LESSONS LEARNED AND RELEVANT RESEARCH

Figure 106 is an attempt to summarize on one page the significant lessons learned from the fires we reviewed, particularly the ones that affected the flight and hangar decks. Certainly a more effective firefighting agent was needed, so now massive quantities of AFFF have been put on all of our carriers. In response to the need for the ability to remotely activate AFFF to control pool fires on the deck, we do now have AFFF systems protecting the entire flight deck and hangar deck. These systems can be activated from either the island for the flight deck or from the Conflag Stations on the hangar deck.

The lesson learned is to have hose lines designed to be rapidly deployed by one person; we now have that with the 1.5-inch flow-through hose reel. Deck-edge areas need a higher application rate, so deck edge nozzles have been back fitted on all carriers. The wind must be considered in system designs and systems tactics, and that factor has been incorporated.

Systems must be reliable and operational ready. The firefighting NATOPS lists a requirement for a formal certification process. Before beginning air operations (AIOPS), the Air Boss and Chief Engineer must certify to the Commanding Officer that all of the AFFF

systems are operationally ready. The utility of the firefighting vehicle was certainly learned, and the new P-25 provides increased capabilities over the old P-16. Standoff for firefighters is important, and even today they are still in jeopardy within 50 ft, so research and development (R&D) efforts are underway to enhance firefighter standoff distance. Running fuel and debris piles are difficult to extinguish; dedicated systems are needed for Bomb Farms and elevators. These systems have been provided. More bomb-jettison chutes have been added around the flight deck, and an appreciation exists that the major threat is weapons cookoff.

After the flight deck fires, specifically the *Forrestal*, *Enterprise*, and *Nimitz*, large-scale R&D programs were run at Naval Air Stations Miramar and Jacksonville, the Naval Research Laboratory, and China Lake. The scope of those test programs is summarized on Figure 107.

Figure 108 is a summary of the current NAVAIR carrier-deck aircraft fire-suppression program. Research is ongoing in each of these areas at both China Lake and Patuxent River.

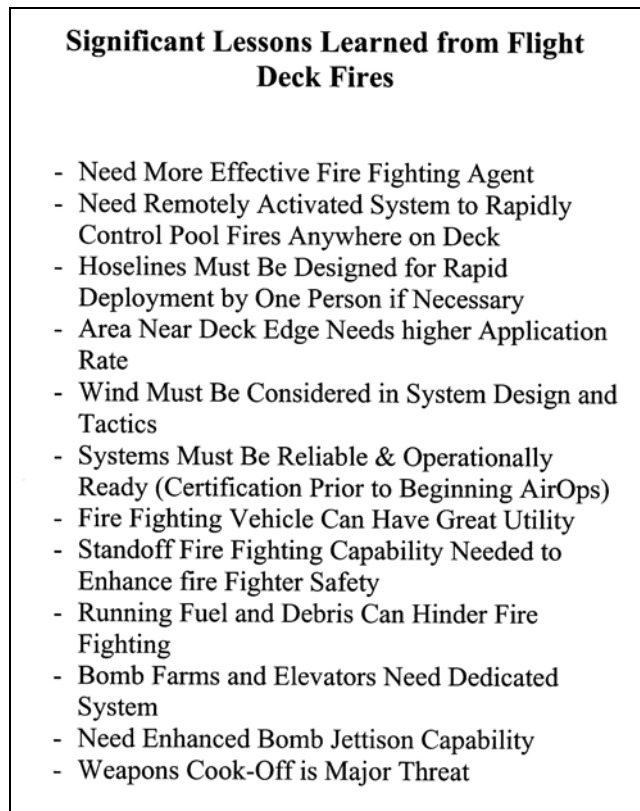


FIGURE 106. Significant Lessons Learned.



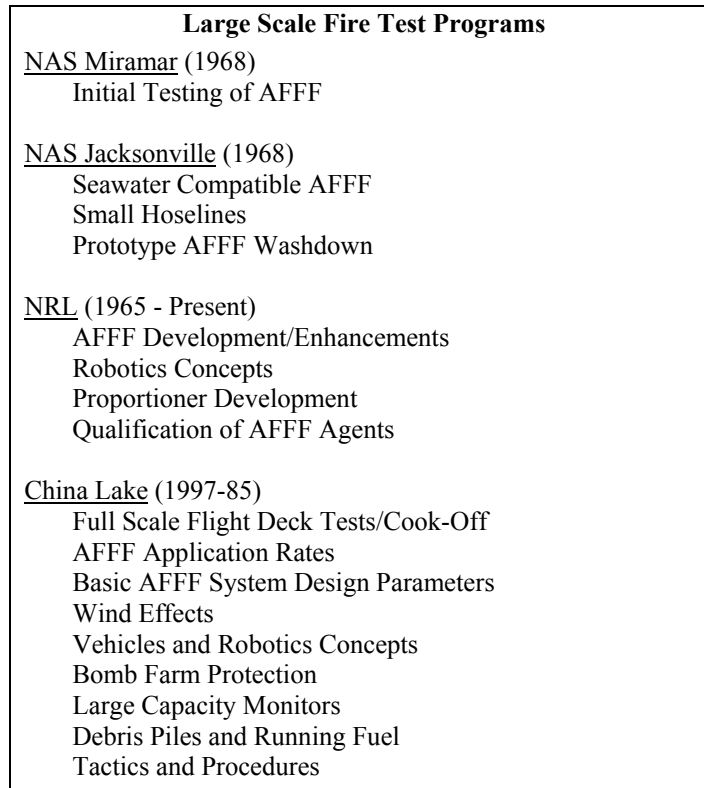


FIGURE 107. Large Scale Tests.

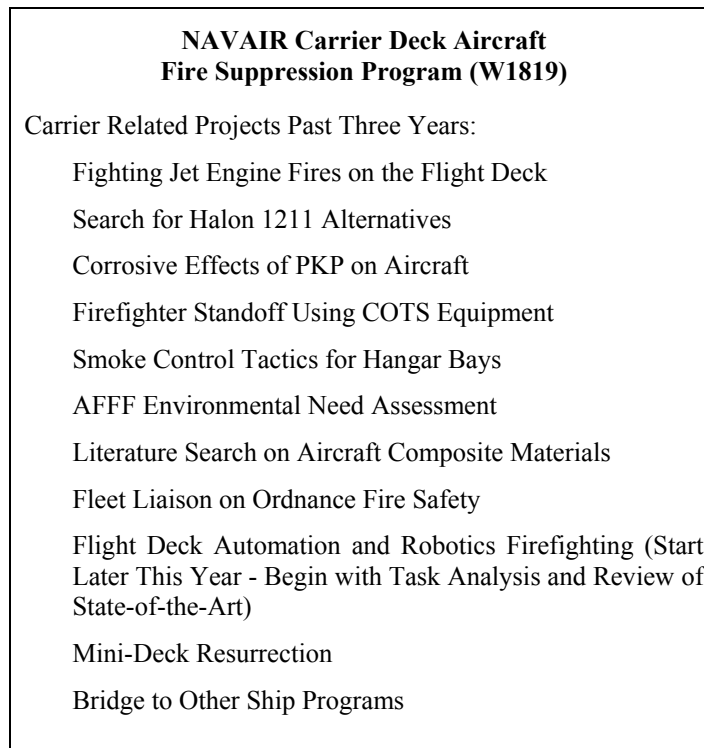


FIGURE 108. NAVAIR W1819 RDT&E.

## CURRENT SHORTCOMINGS AND FUTURE CONCERNS

Figure 109 provides our assessment of the current shortcomings in aircraft carrier fire protection or things that might be of concern in the future. These figures represent an opinion and not necessarily any office of the United States Navy. Their inclusion here may stimulate thought for improvements that might be incorporated in future carrier design or might be considered as part of the LFT&E analysis for CVNX.

Because the deployment of air-launched weapons is the mission of an aircraft carrier, during combat any fires that occur on the flight deck are going to be near ordnance. So, as in the past, the challenge appears to be early cookoff of air-launched weapons. The ability to rapidly extinguish pool fires on the flight deck is essential. AFFF, which is the agent that allows the rapid extinguishment of pool fires, has a cloudy future because of possible environmental issues. If the Navy were forced to curtail the use of AFFF, the fire-protection posture of the flight and hangar deck could be seriously degraded. Of course the current flight-deck conflagration-control system, as effective as it is, is based on 20-year-old technology and does not incorporate the latest in robotics, automation, remote control, sensors, and interactive computer control. This situation forces firefighting to continue to be labor intensive and we still place firefighters in harms way. More effort is needed to get the man out of the loop, to provide more standoff firefighting capability.

A lingering concern (Figure 109) with ordnance is that under current IM criteria no minimum reaction time exists for ordnance exposed to a stimuli, especially for exposure to a flight deck pool fire. Under the current criteria, as long as the reaction is no more severe than burning, the reaction can happen instantaneously. What has not been quantified is the threat of fratricidal burning. Fratricidal burning means that the energetic fill in a piece of ordnance or the propellant burns as an acceptable IM reaction, and the burning of that energetic material or propellant then directly engulfs an adjacent piece of ordnance. The concern is that the flame temperature of burning energetic material (explosives or propellant) is considerably hotter than the flame temperature under which ordnance passes the IM fast-cookoff test. A JP fire, which is used for the cookoff test, will be somewhere between 1,800 to 2,000°F. The burning propellants or explosive fill can be twice that, so fratricidal burning may actually cause a detonation even for ordnance that has been classified as insensitive based on exposure to a JP fire.

Another concern is that the flight deck protective scheme has not been subjected to a vulnerability analysis based on a combat scenario. Recently as part of the validated assessment report (VAR) analysis for CVNX, a postulated hit will occur on both the flight deck and the hangar deck. Concern has always existed about the topside location of the bomb farm and its susceptibility to "cheap kill." Again, relative to the design of the current fire-protection suite, the current layout is based on the specific flight deck design and configuration found on *Nimitz*-class carriers. In other words, the protection for the bomb farm, the way the nozzles cover the elevators and weapons elevator shafts, the way the flush-deck nozzles are positioned, and the location of the deck-edge nozzles is all based on a *Nimitz* layout. If in future versions of the CVNX, major changes were made in the layout, the configuration, or the aviation operations, then the whole system might have to be redesigned.

- As in the past, the biggest challenge is the early cook-off of air-launched ordnance when exposed to fire (rapid extinguishment of pool fires is essential)
- AFFF, the agent that permits the most rapid extinguishment, has a cloudy future due to possible environmental effects.
- Current approach is labor intensive and places firefighters in harm's way. More standoff firefighting capability is needed to get the man out of the loop. Future manning reductions on carriers will necessitate development of non-manual concepts.
- The current flight deck conflagration control system is based on 20-year-old technology and does not incorporate state-of-the-art sensors, robotics, automation, and interactive computer control.
- There is no minimum reaction time for ordnance (burning is allowed immediately) and threat of fratricidal burning on adjacent ordnance has not been quantified.
- Current design of flight deck protective scheme has not been subjected to a vulnerability analysis based on combat scenarios. A direct weapon hit on a pack of armed and fueled aircraft has not been quantified.
- The current fire protection suite is based on the specific flight deck layout and configuration found on current *Nimitz*-class carriers. Change in layout, configuration, or air operations will necessitate redesign to maintain current capability.
- The threat to ordnance during upload and download from the flight deck has not been quantified. The potential exposure of ordnance along the entire route of travel to/from the magazines should be analyzed.
- Current ability to rapidly extinguish aircraft debris piles (where there are limited successful avenues of approach) and fires on the bow (where there are no means of staging an attack with-the-wind) is suspect.
- The current AFFF solution feed to the flight deck lacks redundancy (the supply piping to each demand point is single, vertical, non-looped). Except for hangar bay sprinklers, each AFFF demand point is fed AFFF solution from only one AFFF proportioner station. For example, each AFFF hose station, each AFFF washdown zone, and each AFFF deck-edge zone is fed from one and only one AFFF proportioner station on the second deck.
- Future carrier operations may involve joint and allied operations. The threat posed by new and different aircraft, fuels, and ordnance needs to be assessed.
- Automated aircraft arming and fueling concepts should integrate novel fire protection features.
- Current hangar bays lack fire detection. Detection is based on human observation from continuously manned conflag stations. Development of reliable detection for hangar bay fires could free up valuable manpower.
- A weapons hit in the hangar bay could render the overhead sprinklers inoperative and might also cause the side elevator doors to be jammed shut. Manual firefighting with jammed side doors may be overly challenging since heat, flames, and smoke, lacking an exit path to weather, would rapidly descend to the firefighter level. An analytical assessment should be conducted of the vulnerability of the hangar sprinkler system and door controls, as well as the ability of hose teams alone to combat a major hangar bay fuel fire.
- The ability to prevent vertical fire spread from a hangar bay fire should be assessed using fire and smoke spread modeling and simulation. Large scale fire testing may be warranted. Exposures adjacent to the hangar bays (such as sponsons, shops, HAZMAT handling areas, mogas storage, aircraft maintenance areas, etc., as well as fire boundaries, containment, vertical and horizontal openings and penetration tightness should all be considered in performing a hangar deck vulnerability study.

FIGURE 109. Current Shortcomings and Future Concerns.

The threat of ordnance when it is not located in the magazine has not been quantified (Figure 109). Currently a program funded by NAVSEA quantifies the fire threat to ordnance along the entire route of travel to and from magazines. We know that the extinguishment of fires in aircraft debris piles and on the bow, where limited successful avenues of attack may exist, has always been a weakness of our current firefighting system. From a redundancy standpoint, the arrangement of the current AFFF systems (where the piping to each demand point is single, vertical, and non-looped) is certainly of concern. Except for the hangar bay, each AFFF demand point is fed from one and only one AFFF proportioner station on the second deck. Perhaps future carrier designs could provide redundant feed to all AFFF demand points.

Concern exists about the difference in aircraft, fuel, and ordnance that may come aboard as a result of joint and allied operations. Operations with the Army, Airforce, and especially with allied NATO countries, are going to result in ordnance coming aboard that we are not familiar with, or ordnance that may not have passed an IM program. They may come aboard with different fuels and different aircraft. This needs to be assessed. Our ships must be ready to take on different ordnance, fuel, and aircraft.

Any attempts at automated aircraft arming and fueling should consider the integration of novel fire-protection features as part of the designs of those new fueling or arming systems. Consideration should be given to installing modern detection systems in hangar bays. Right now the detection is based on human observation from a Conflag Station. Valuable manpower could be freed up by the installation of reliable detection systems. We are concerned about the ability to handle a weapon hit in a hangar bay. A hangar bay hit will be included in the VAR analysis for CVNX.

## REFERENCES

1. MIL-STD-2105B. (See page 31)
2. Naval Air Systems Command. *NATOPS U.S. Navy Aircraft Firefighting and Rescue Manual*. Washington, D.C., NAVAIR, 1 September 2001. (NATOPS 00-80R-14, publication UNCLASSIFIED.)
3. \_\_\_\_\_. *Naval Air Training and Operating Procedures Standardization (NATOPS) Manual*. Washington, D.C., NAVAIR, 21 October 1999. (NATOPS CV NAVAIR 00-80T-105, publication UNCLASSIFIED.)
4. \_\_\_\_\_. *Servicing Trailer, Liquid Oxygen, Low Loss, Closed Loop Illustrated Parts Breakdown*. Washington, D.C., NAVAIR, 30 September 2000. (NAVAIR Reference Manual 19-25D-26, publication UNCLASSIFIED.)
5. \_\_\_\_\_. *Naval Air Training and Operating Procedures Standardization U.S. Manual on Aircraft Refueling*. Washington, D.C., NAVAIR, 30 May 1999. (NATOPS 00-80T-109, publication UNCLASSIFIED.)

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